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DILUTE: A MINI-CAMPAIGN SIMULATION MODEL TO ANALYZE STRATEGIC PENETRATION OF VARIOUS FORCE MIX COMBINATIONS OF CRUISE MISSILES AND MANNED PENETRATORS

THESIS

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THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
Air University
In Partial Fulfillment of the
Requirements for the Degree of
Master of Science

by

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Graduate Strategic and Tactical Science

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Abstract

This study develops a computer simulation model of manned and unmanned penetrators in a strategic scenario in order to evaluate the effects of various force mix combinations of cruise missiles and manned bombers. The model is largely based on three generations of strategic weapons to be used in a strategic conflict. In general, the model uses data based on current, projected, and future technological developments in the areas of strategic penetrators and uses this data to measure the synergistic effects of various combined manned/unmanned penetrator strike forces in terms of survivability and the ability to inflict the required level of damage to the enemy target base. The model, called DILUTE, is written in SLAM, using extensive FORTRAN inserts and is designed to allow for considerable flexibility and user control.

The experimental design uses a full factorial design with three factors: radar cross section, speed, and force mix. These factors are analyzed for significant effects on the value average probability of damage. In using an analysis of variance the three factors were found to be significant.

The results of the study indicated that significant differences do exist between force mix combinations of ALCM and manned penetrators, however the results are highly dependent upon the factors of radar cross section and speed. Bomber survivability against peripheral defenses of surface to air missile threats can be significantly enhanced if the bombers are used in concert with cruise missiles due to the def-

ense dilution aspect of the ALCM. The same effect was determined in the airborne interceptor threat, as long as the airborne interceptor had a reasonable chance of detecting the ALCM. Enhancement of bomber survivability by ALCM dilution at the terminal surface to air missile threat was determined not to be statistically significant at the 1% level. Additionally, it was realized that pure forces dominate mixed forces; the dominant characteristics being electronic countermeasures for the bomber and saturation for the ALCM. Finally, the decisions on force mix are heavily dependent upon radar cross section and speed improvements, with the manned penetrator being a much more effective weapon system than the ALCM when technological improvements in speed and radar cross section are employed.

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I. Introduction

Background

The continual research and development of Soviet air defenses poses a significant challenge to military planners. Our strategic bombers continue to be an effective component of the TRIAD, however their usefulness against heavily defended strategic targets becomes questionable as the number of Soviet manned interceptors and GCI sites multiply, and new defensive systems are phased in.

The strategic mission of our bomber force is to penetrate Soviet defenses at low altitudes avoiding known and suspected defenses and strike their assigned targets. The agency responsible for strategic nuclear weapon targeting is the Joint Strategic Target Planning Staff (JSTPS). In broad terms the JSTPS uses three inputs in generating the Single Integrated Operations Plan (SIOP) (Ref 1:40). First is the guidance that is levied upon them from the Joint Chiefs of Staff (JCS). The SIOP is merely the plan that puts into action JCS broad term goals and strategy.

The second input is the force structure that the JSTPS may use in plan development. Each Commander-in-chief (CINC) of the Unified and Specified Commands has requirements to commit certain forces to JSTPS in support of the SIOP.

The third input is intelligence data gathered from all civilian and military resources. From this data potential targets are selected,

categorized, and prioritized in accordance with JCS guidelines.

Within the JSTPS there are two main divisions responsible for plan development. The NSTL (National Strategic Target List) Division issues the National Strategic Target Base (NSTB) which describes and categorizes all potential targets. It is from this list that targets are grouped into complexes, and from which aimpoints, or Designated Ground Zeros (DGZs) are selected. The SIOP division then applies the forces committed to the SIOP, assigning the delivery vehicle/weapon combination on the DGZs (Ref 1:44). In assigning each sortie, whether ICBM, SLBM, bomber, or cruise missile, the SIOP division uses JCS planning factors in determining Prelaunch Survivability (PLS), Weapon System Reliability (WSR), and Probability to Penetrate (PTP).

The four phases of a strategic mission profile are prelaunch, enroute, forward air defense (may include Airborne Warning and Control System (AWACS) aircraft), and in-country penetration.

The prelaunch phase consists of those surviving bombers launching from CONUS bases who proceed enroute to their assigned targets. Surviving bombers are air refueled by surviving tanker aircraft to give the bomber the distance needed to get to his assigned target, which may lie deep inside enemy territory. The Forward Air Defense (FAD), usually located outside of the enemy's target area, consists of AWACS aircraft which vector fighter interceptors to the penetrators before the penetrator has the opportunity to penetrate in-country. Finally, the in-country phase is where the penetrator can expect to encounter Early Warning (EW) and Ground Controlled Intercept (GCI) radars as well as Surface to Air Missile (SAM) sites and fighter Airborne Interceptors (AI). This study

considers only the in-country penetration phase of a strategic scenario. The study implies that the penetrators are those that have survived (with no degradation) the previous three phases. Once the penetrator is in-country, the air battle begins with the interaction of bombers and cruise missiles over the enemy's defended air space.

Our current manned penetrator, although large in visual, IR, and RCS signatures can react to enemy threats with electronic countermeasures (ECM) and maneuvers. The manned bomber also has a limited stand-off capability with the Short Range Attack Missile (SRAM). However, its existence since the 1950's concerns our leaders as to whether it can still retain the flexibility and vitality of the air breathing leg of the strategic TRIAD.

A steady and sustained increase in Soviet military strength is undeniable. Soviet strategic forces have grown from a position of clear inferiority in the mid-1960's to one of rough strategic parity with the United States (Ref 2:7). They have also complemented their numerical superiority with marked qualitative improvements in nearly every aspect of combat capability.

This raises the question whether or not our existing bomber fleet is capable of penetrating large numbers of new, advanced Soviet defensive systems. If one concludes that a manned penetrator is still an effective strategic weapon system and a viable strategic deterrent, then the question remains how to effectively use this weapon system to inflict unacceptable levels of damage to the enemy's target base.

An important addition to the future United States strategic bomber force is the Air Launched Cruise Missile (ALCM). This missile will pro-

vide the United States with a mixed standoff/penetrate force which will complicate Soviet defenses by saturating ground and air based defensive systems. The ALCM will supplement the penetrating bomber and will have the capability to damage or destroy both soft and hard strategic targets. The current generation cruise missile is a weapon system design consisting of a small radar cross section (RCS), with speeds approximating mach .6, and capable of delivering a weapon within a few feet of a DGZ. The cruise missile can be launched by bombers penetrating Soviet defenses or by bombers entirely outside of the defenses. The problem facing our military planners today is how to effectively employ this new strategic weapon system. This thesis effort is designed to study the effects of different force mixes of bombers and cruise missiles in a strategic penetration of the Soviet land mass.

Problem Statement

The problem, in general terms, is to measure the synergistic effects of a combined manned/unmanned penetrator strike force in terms of survivability and the ability to inflict the required damage level to the enemy target base. Specifically, the measurement of the relative effectiveness of the combined bomber/ALCM force is reduced to the following subproblems:

1. Is there a significant difference between force mix combinations of ALCMs and bombers in terms of damage inflicted on the enemy target base?

2. Is there a significant difference in the survivability of the bomber force when interspersed with a force of penetrating cruise missiles?

3. Does one weapon system dominate the other?

4. Are the answers to the above questions dependent upon future technological advancements in penetrator speed and radar cross section?

Objectives

The objective of this thesis is to develop a computer model which will measure the survivability and the damage inflicting capability of a combined strategic strike force. The model will be used as the source for data inputs into a statistical experimental design which will:

1. Test for significant differences in damage effectiveness between different force mix combinations.

2. Test for significant differences in bomber survivability between different force mix combinations.

3. Test for overall dominance of one weapon system over the other.

4. Be able to perform sensitivity analysis on the factors of Speed and RCS in order to determine if technological improvements in these areas will change the results of the tests performed above.

Problem Assessment

The process of developing a plan for strategic attack can be divided into four parts: (1) identifying and selecting strategic targets; (2) ranking these targets in order of priority; (3) designating the appropriate attack weapons against the targets; (4) developing the attack timing structure (Ref 3:16).

The purpose of the plan is to insure that maximum damage is inflicted upon the enemy. The factors that impact upon the term "damage" are represented conceptually in the Causal Loop Diagram shown in Figure 1. The system of +'s and -'s represent direct or inverse relationships between the factors.

A measure of effectiveness used in determining damage levels is called Damage Expectancy (DE). DE is the multiplicative probability of several independent events and is defined by the following equation:

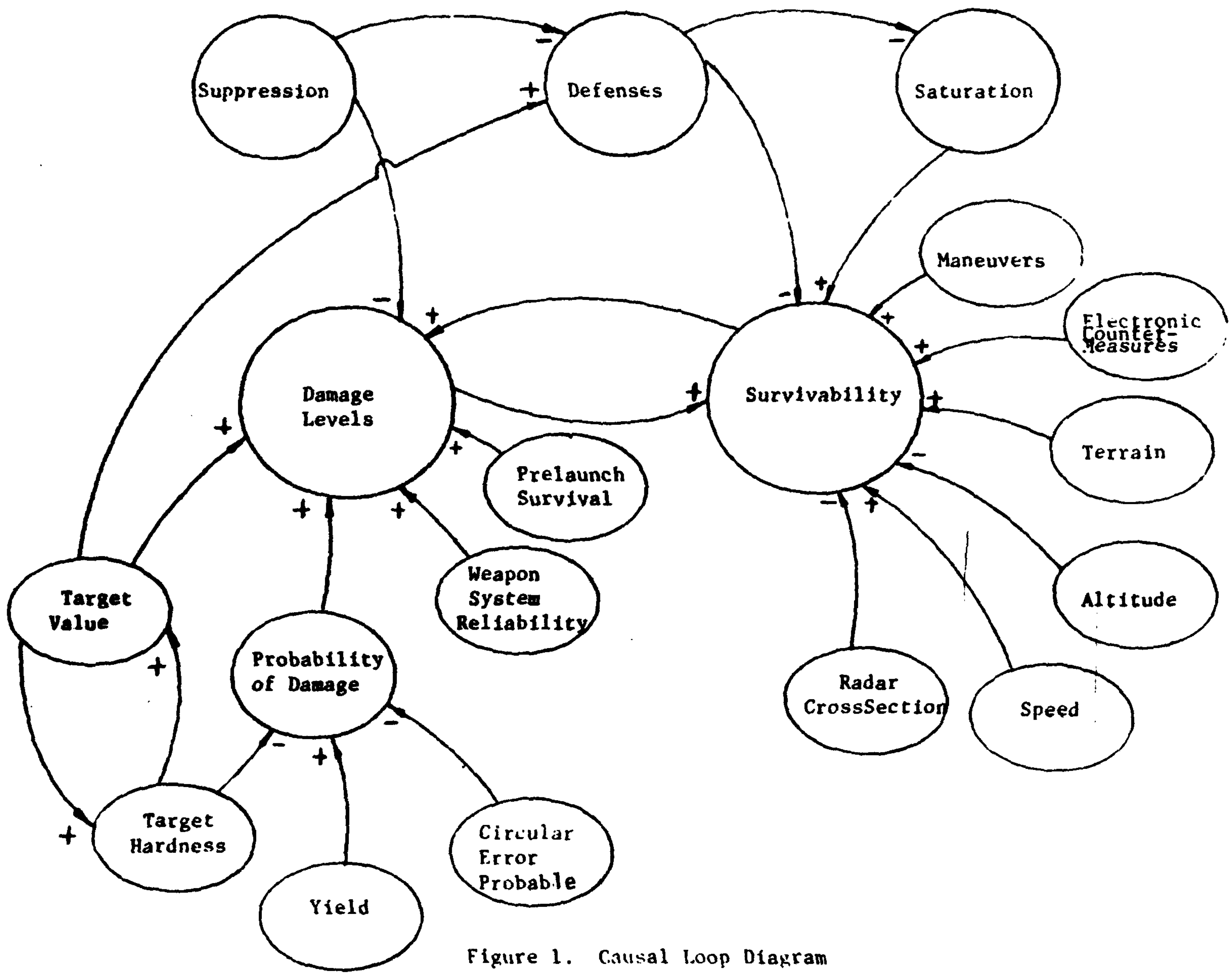


Figure 1. Causal Loop Diagram

$$DE = PLS \times WSR \times PTP \times PD \qquad (1)$$

where:

PLS= Prelaunch Survivability

WSR= Weapon System Reliability

PTP= Probability to Penetrate

PD = Probability of Damage

The first three terms comprise the concept of weapon arrival to the target "area" and fuzing as designed. PTP is represented in the Causal Loop Diagram as Survivability. The last term, PD, represents the concept of inflicting a quantifiable (via blast, overpressure, or gust) damage criterion to the target and is represented in the diagram as a function of target hardness, weapon yield, and weapon Circular Error Probable (CEP).

DE is then weighted for the value of the target. The method used to categorize and assign values to targets is called significance analysis (Ref 3:19). The method involves ranking installations within various categories by their value to the enemy and their value to the United States in terms of the degree to which elimination of the particular target meets national security objectives. Target value can be assumed to be proportional to the level that the target is defended. When the defense deploys in proportion to value then the number of defenders per unit target value is constant (Ref 4:75). For this analysis it is assumed that all targets have equal value, thus they are equally defended and are all of the same hardness. Thus, in terms of relative effectiveness, the measure of effectiveness can be expressed just in terms of PD. This measure of effectiveness will be termed Value Averaged Probability of

Damage (VAPD) and will be defined as the proportion of the value of the enemy target base destroyed.

As shown in Figure 1, the strategy of defense supression reduces the level of defenses. However, the price of this strategy is in the sacrifice of weapons which could have been allocated to the target base. A strategy of saturation by penetrating within a small number of corridors and with increasing arrival rates tends to increase survival probabilities (Ref 4:128), (Ref 5:64). The factors of RCS, Altitude, and Terrain affect the ability of the defense to detect the penetrator. Once detected, ECM, Speed, and Maneuvers may be employed to negate the opportunity for successful engagement.

Methodology

As problems become more complex the need for a conceptual framework both for the problem definition and for its solution becomes more acute. The system science paradigm found in Schoderbek, Schoderbek, and Kefalas (SSK), "Management Systems" was instrumental in developing an approach to capture the complexities of modeling a strategic penetration with various force mix combinations of manned and unmanned penetrators. The system science paradigm consists of three phases: (1) Conceptualization, (2) Analysis and Measurement, (3) Computerization.

Conceptualization. The conceptualization phase consists of understanding the problem at hand, identifying the basic elements of the problem, breaking out these elements and defining their internal operation, then focusing on the interactions, and finally designing a model which will effectively capture these interactions. These steps are summarized in Figure 2.

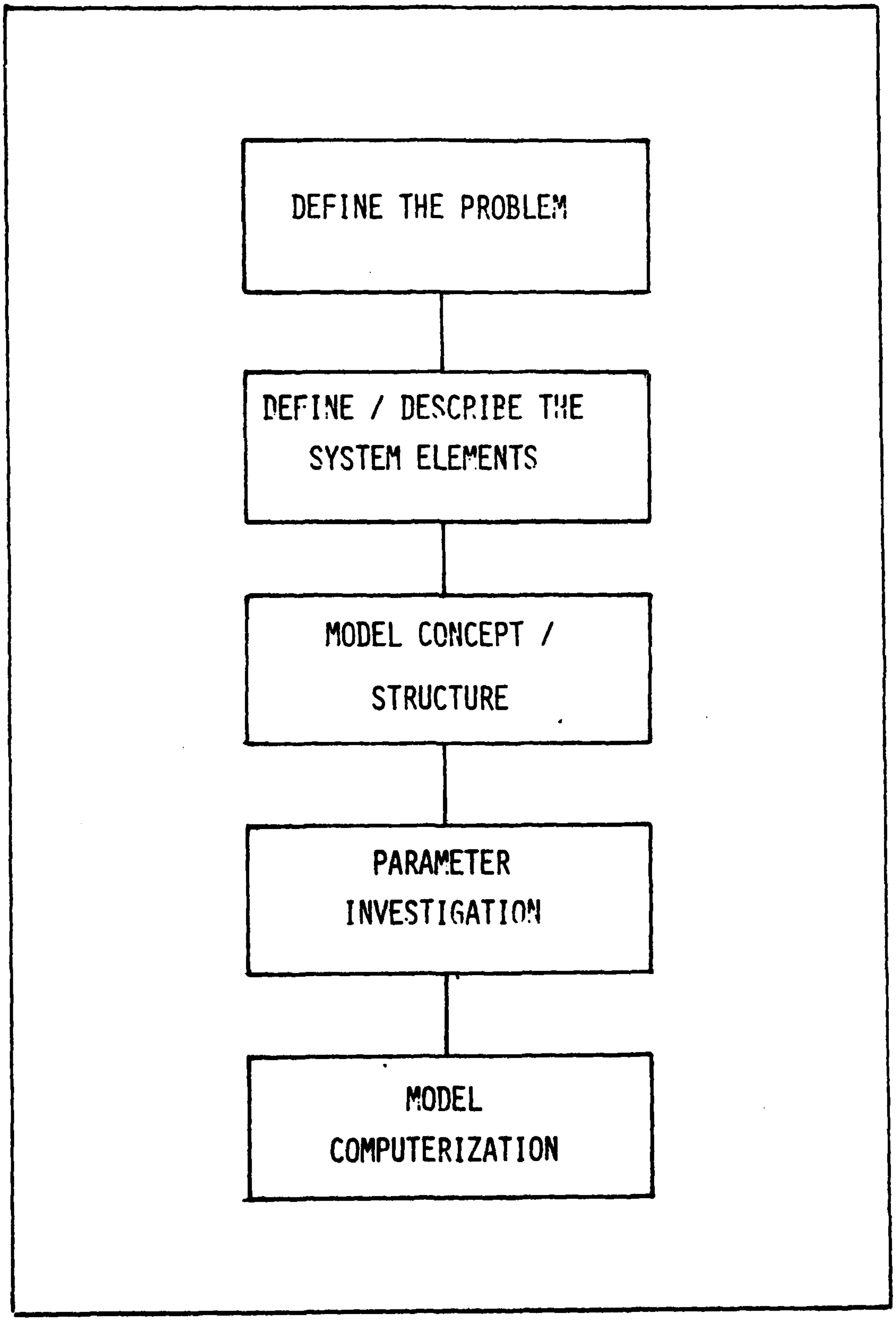


Figure 2. Conceptual Flow Diagram

Analysis and Measurement. In order to begin to measure these interactions the model must be quantified. In other words, some numerical relationships must be developed. These mathematical relationships form a parametric model, which is the goal of the Analysis and Measurement phase. The understanding of the systems developed in the conceptualization phase of systems thinking is vital for the development of the parametric or mathematical model.

Computerization. In developing a model to help solve the problem one needs to keep in mind that the model is a representation of the real world phenomenon but with much less detail. A model includes only those factors or elements that are absolutely necessary for a rough description of the real world. However this does not imply that a model must be simple. As stated in Schoderbek, Schoderbeck, and Kefalas (Ref 6:284):

> "The apparent simplicity involved in the modeling process is only of a temporary nature. It is used as a means of comprehending the complexity inherent in the (real world). The ultimate 'system' which will be used to deal with the real world situation must be as complex as the real phenomenon... That is, of course, dictated by the universal law of requisite variety: one deals with complexity through complexity."

The complex real world phenomenon in this study involves numerous stochastic processes including arrival rates, courses flown, weapon impacts, weapon effects, levels of target destruction, defense suppression, defender reactions, and defense saturation, exhaustion, and elimination. Simulation modeling was chose instead of closed form analytical solutions because simulation better captures the synergism of different offensive weapon systems interacting in a battle area with a dynamic defense environment.

SLAM (Simulation Language for Alternative Modeling) was chosen because it provides a highly flexible modeling framework of graphical models that are easily translated into input statements for direct computer processing. The SLAM structural model is composed of a network structure that supports discrete event orientations, along with event oriented FORTRAN subroutines. The SLAM processor is FORTRAN based and can support extensive user written FORTRAN subroutines to enhance the SLAM structural model. The SLAM structural model is presented in Appendix A.

Scope

To say that the scope of this problem is massive is an understatement for there are thousands upon thousands of potential targets scattered over millions of square miles of land mass (Ref 2:19). To limit the size and scope of the model while still providing an adequate representation of the real world phenomenon some major assumptions were made:

1. The target base consists of 200 highly valued, terminally defended targets concentrated in an area encompassing approximately 60,000 square nautical miles.

2. All targets are of equal value and equally defended. The target hardness is fixed to that of a 13Q7 DIA Greenbook target.

3. A major portion of the defense suppression effort is considered to have already been accomplished. Thus the defenses remaining are those defenses after the suppression dedicated weapons have been expended.

4. The weapon to target ratio is 2:1.

5. The bomber can employ ECM and maneuvering techniques while the ALCM cannot.

6. There will be only one type SAM system which will be an hypothesized future generation, mobile SAM referred to as the SA-X.

7. The AI threat will be an hypothesized future generation fighter with an advanced LDSD capability.

This study does not include tactical SAM systems or AAA. These systems are deployed with Soviet ground armies and are not expected to be a significant factor in a strategic penetration scenario. (Ref 7), (Ref 8). Tieing together the objectives of this study, the conceptual framework, and the methodologies, one can represent the system being studied in the form of a structural model shown in Figure 3.

Structural Model

In developing the structural model, consideration was given to the number of targets, the size of the land mass, and the defense levels. In a previous study of manned penetrators and cruise missiles (Ref 9:17) the variance of he response variables fluctuated excessively from one force mix size to another. In order to obtain more run to run variance stability, runs were accomplished using larger numbers of penetrators. From this study it is estimated that a force size of at least 40 manned bombers was necessary to provide a minimum force size for evaluation of the interactions and to provide a more stable variance. A typical weapon load for a bomber is considered to be 10 weapons comprised of 4 gravity bombs and six SRAM. Thus this force has 400 offensive weapons. Other force mixes will be combinations of bombers and ALCMs which also yield 400 weapons.

As previously stated, a 2:1 weapon to target ratio is assumed. Therefore there will be 200 DGZs in the target base. A DGZ density of $300 nm^2$ per DGZ was considered to be representative of a dense target environment. To support 200 DGZs a $60{,}000 nm^2$ land mass is required.

The principle of concentration of force was used in establishing two entry corridors in an attempt to saturate the BSAM. Once passed the

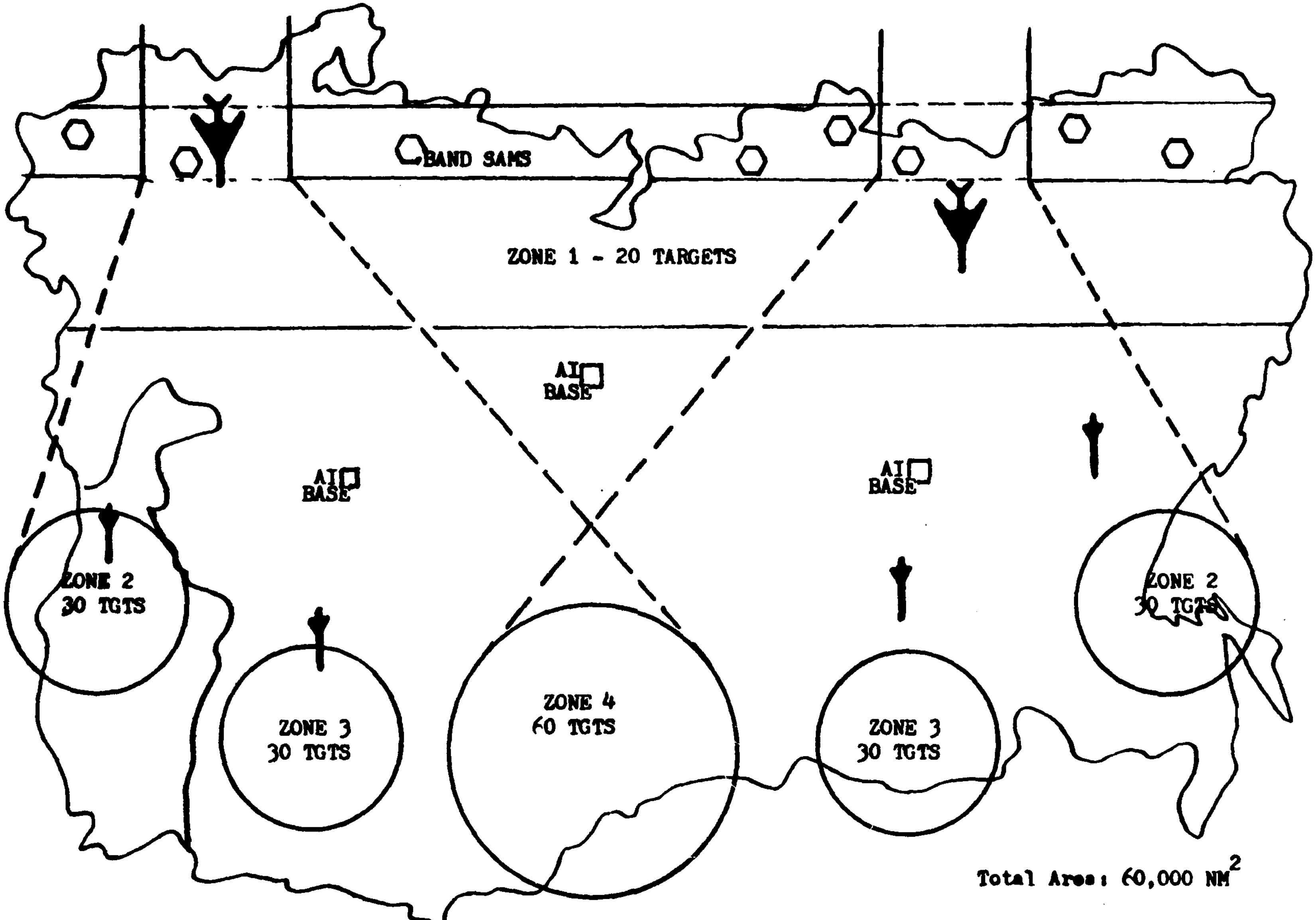


Figure 3. Structural Model

BSAM the penetrator enters the AI area. In this area are the GCI/C^3 facilities. A GCI site density 150 per million square kilometers was used. Therefore the model begins with 25 sites. Of these 25 sites 20 are targeted. This GCI/C^3 target group will be referred to as Zone 1 targets and are not differentiated by corridor.

The terminally defended target zones are located following the Zone 1 target group. Penetrators entering from corridor one fly representative distances to Zones 2 and 3 on the left side of the map and to Zone 4 in the middle. Penetrators entering corridor two fly to their respective Zones 2 and 3 on the right side and to Zone 4 in the middle. Zone 4 merges the two corridors and supports twice the number of targets (and twice the defenses) as Zones 2 or 3. The following is the target distribution by zone:

	TGTS
Zone 1	20
* Zone 2	30/30
* Zone 3	30/30
Zone 4	60

* one in each corridor

The penetrator is vulnerable to the AI threat from Zone 1 to entering the terminal threat area. The AI threat is comprised of 50 fighters having an advanced LDSD capability. Only 80% of these fighters are considered mission capable and able to engage in the air battle. Any fighter may be assigned to any penetrator regardless of corridor entry. Zones 2 and 3 are each defended by one SAM site while Zone 4 is defended by two SAM sites.

Overview

Explained in detail in the remainder of this thesis is the model development, the simulation structure, the analysis of results, and conclusions. More specifically, discussed in Chapter II are the components and concepts incorporated in the model development. Discussed in Chapter III are the concepts incorporated in the simulation model. Discussed in Chapter IV is the Experimental Design. Contained in Chapter V is the Analysis of Results. In Chapter VI is the Verification and Validation of the model. Included in Chapter VII are the Conclusions and Recommendations. The final chapter, Chapter VIII, discusses possible Recommended Areas for Further Study.

II. Model Development

The model, called DILUTE, was developed by the authors to help analyze the problems stated in Chapter I. This chapter presents the methodology involved in developing the structure for DILUTE. The main components of this structure are: penetrator arrival patterns, penetrator target assignments, defense structure to include both SAM and AI, and weapons effects calculations. DILUTE was developed in a building block concept similar to the Advanced Penetrator Model (APM) (Ref 10:88). Figure 4 shows the main blocks of DILUTE. Each block was developed separately for ease of verification. This chapter will present the methodology involved in developing each of these blocks.

Arrival Rates

Minimum feasible interarrival times were set to enhance saturation effects. Actual arrival times are stochastic processes due to inherent imperfections in the systems which control the arrival times. Bomber interarrival time was modeled by a lognormal distribution with a mean of 3 minutes and a standard deviation of 45 seconds. A lognormal distribution was chosen because its median is less than its mean and this is typical of bomber navigation time control deviations. An exponential distribution was not used because an exponential distribution assumes large variability (Ref 11:31). Three minutes was chosen as representative of planned spacing of bombers based upon current Red Flag training excercises.

Since ALCMs have preprogrammed, fully automated navigational systems their arrival pattern was modeled by a normal distribution with

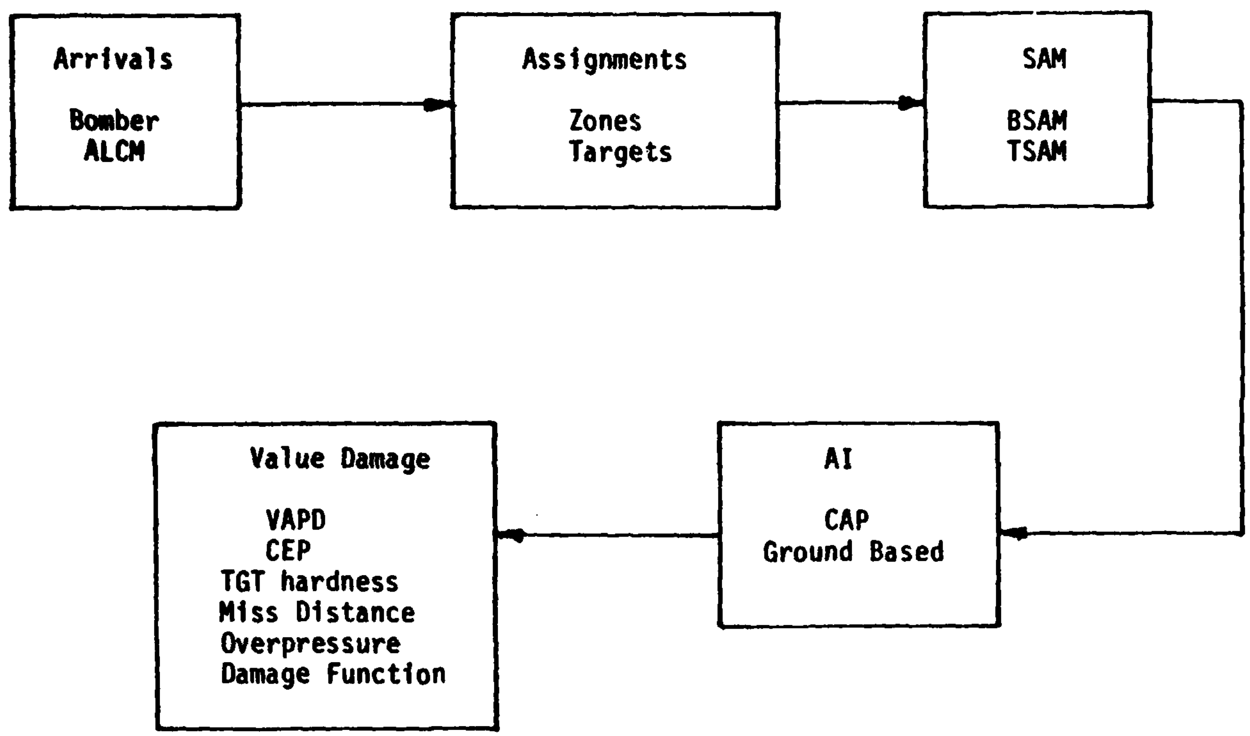
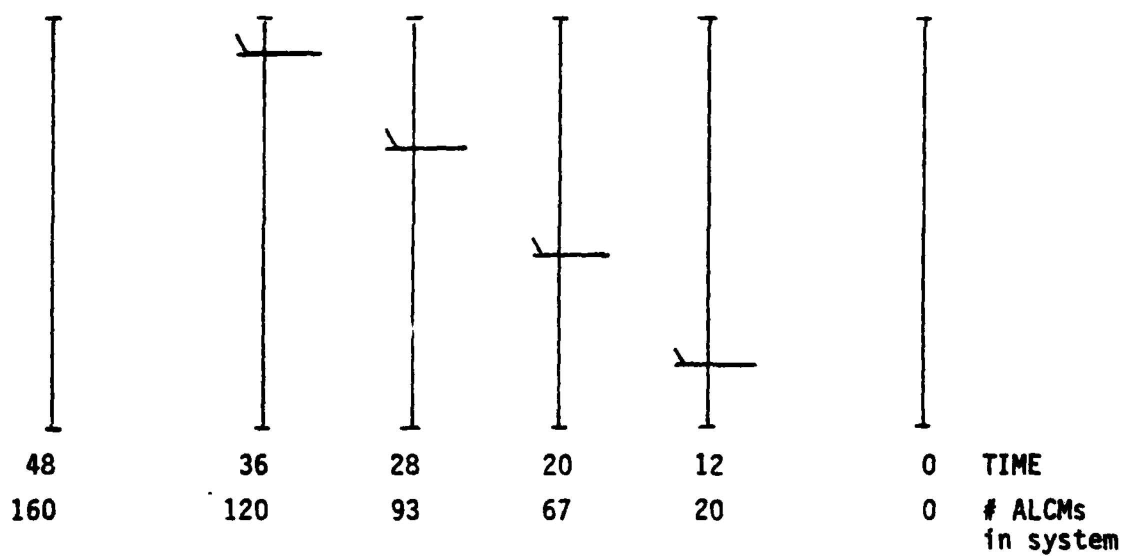


Figure 4. Modeling Sequence Diagram

a mean of .3 minutes and a standard deviation of 15 seconds. Faster arrival rates are justified for the ALCM because it is smaller, more numerous, and has a more accurate navigational system allowing for better timing precision.

These arrival times were adjusted for different force mix combinations to allow for proper interspersing of the forces. As an example the following timing plan was used for a single corridor of 160 ALCMs and four bombers:



For this force mix the bomber force was delayed 12 minutes at each corridor to allow some ALCMs to enter the system. Then the bomber arrivals commenced with a mean time between arrivals of eight minutes. If the bomber arrival pattern had not been adjusted from their minimum feasible values then all four bombers would have entered the system within nine minutes and there would have been no interspersing effects. The time

table for the different force levels is shown below. Each corridor follows the same schedule:

	ALCM		Bomber	
	mean	delay	mean	delay
200 ALCM/ 0 Bombers	.3	0.	-	-
160 ALCM/ 4 Bombers	.3	0.	8.	12.
100 ALCM/ 10 Bombers	.3	0.	3.	0.
40 ALCM/ 16 Bombers	1.1	2.	3.	0.
0 ALCM/ 20 Bombers	-	-	3.	0.

These were the timing plans used for the different force mix levels in DILUTE. The next section describes the target assignment structure.

Target Assignments

This section develops the mission profiles of the penetrators and discusses the strategies used in the target assignment process. To limit the realm of possible strategies, all targets are equally hardened, valued, and defended. While the Zone 1 targets do not have dedicated SAMs defending them, they may be considered terminally defended due to their proximity to the BSAM (Ref 12:10).

All bombers have the same mission profile. Bombers must attempt to penetrate the BSAM. Each bomber is assigned a gravity weapon release on a Zone 1 target. An advantage of the bomber is its standoff capability with the SRAM. In order to exploit this advantage, the bomber proceeds to Zone 2 and Zone 3 but does not need to penetrate the terminal defense. The SRAM is launched in a semiballistic profile for maximum range at the periphery of the Terminal SAM (TSAM). Each bomber is assigned three SRAMs against Zone 2 and three SRAMs against Zone 3. The bomber's remaining gravity weapons are targeted in Zone 4. The

bomber must penetrate the Zone 4 TSAM to deliver the gravity weapons.

Each ALCM is assigned one target. The first 10% of the ALCM force is targeted in Zone 1. This strategy of targeting the front end of the ALCM force at the GCI/C^3 sites will assist those lead bombers already in the AI area as well as the follow on ALCMs because the mean time between AI encounters will depend upon the number of these sites that have not been destroyed.

Once the penetrators are assigned to their respective zones, the individual targets are assigned to each penetrator sequentially based upon the type of penetrator and the number of penetrators that have entered the system.

SAM Encounter

The SA-X is a mobile SAM system. The effect on the offense then is that pre-penetration defense suppression cannot be planned for with certainty. If sites are attrited, the other sites may redeploy to cover the gaps created. In this way the BSAM is modeled with a uniform site density of one site every 30 nm providing continuous peripherial defense of this sector of land mass. TSAMs are similarly deployed with one TSAM protecting 30 DGZs. Unlike older SAMs, the SA-X has three launchers with one TTR (Target Tracking Radar). Three targets may be tracked simultaneously and the launchers may track separate targets. Thus each site may simultaneously engage three penetrators which complicates the saturation problem. Each launcher has a capacity of four missiles. Missiles may be reloaded from ready storage. Missiles are stored at the sites based on a 3:1 stockpile to launcher loading.

The system parameters shown below were used in modeling the SAM.

The data presented here is hypothetical but represents a close enough approximation of an improved SAM system to perform the comparisons necessary for this study. For an explanation of the terms presented below see Table 1.

P_t	50 dBW
G_t	43 dB
G_r	40 dB
N	18 dB
kT_o	-144 dBW/MHz
λ	-16 dB
B_t	8 dB
L	12 dB

The following were the operating characteristics modeled for the SAM site.

Missiles per launcher	4
Launchers per site	3
Missiles in ready storage	36 per site
Time for lock on	15 secs
Time between launches	3 secs
Reload time	1 min + 1 min per missile
Maximum forward range	20 nm
" side range	15 nm
Minimum range	5 nm
Average missile velocity	2300 knots

Table 1

This table contains an explanation of the radar system terms used in describing the SAM system.

P_t = power transmitted in decibels above 1 watt

G_t = effective antenna gain in transmit

G_r = effective antenna gain on receive

N = received pulses during one beamwidth

k = Boltzman constant (1.38×10^{-17} MegaJoules/ ^{o}K)

T_o = reference temperature, 288 ^{o}K

λ = transmitter wavelength

B_t = transmitter bandwith in decibels above 1 MHz

L = system losses due to non-coherent integration of pulses

R = range in meters

S/N_{min} = the minimum signal to noise ratio required for target detection where S/N is the ratio of the target return power to the system noise power.

σ = target radar cross section (RCS) in square meters

The remainder of this section will discuss the following areas concerning the SAM encounter:

Detection
Launcher Assignments
CEP Determination
Target Kill
Engagement Sequence

<u>Detection</u>. The detection of a penetrator by early warning and search radars requires that the radar have sufficient power, sensitivity, and subclutter visibility and that the penetrator not be masked by terrain features. The following is an equation for maximum "free space" radar detection range assuming non-coherent integration of the received radar pulses (Ref 13: B-12):

$$R = \left\{ \frac{P_t G_t G_r \lambda^2 N}{(4\pi)^3 k T_o (S/N)_{min} L} \right\}^{1/4} * \sigma^{1/4} \tag{2}$$

As shown in the above equation, the maximum detection range is directly proportional to the fourth root of radar cross section. Search radars are designed to be able to detect penetrators at long ranges and high altitudes. The fourth root range dependence on RCS therefore gives early warning radars excess sensitivity at low altitude (Ref 14:16). A typical early warning radar can have a maximum detection range of 200 nm against a $1m^2$ (one square meter) target. At low altitude it is usually impossible to obtain a line of sight beyond 30 nm (Ref 15:36). This means that an RCS reduction from 1 m^2 to approximately $.0005m^2$ is necessary before RCS

becomes significant. For this reason RCS is not considered a factor in the initial detection of low altitude penetrators. The dominant factors to be considered are line-of-sight (LOS) range and terrain masking. This is supported in a study done by the Calspan Corporation (Ref 16:86).

The distance at which there exists a clear LOS is a function of radar antenna height, type of terrain, and penetrator altitude. The hypothetical terrain model used in this study is shown in Figure 5. In order to determine the initial range of detection, the following curve fit of Figure 5 was used:

$$R_o = \begin{cases} (540000 * x)^{.257732} & \text{if } x \leq .2068 \\ 20. & \text{if } x > .2068 \end{cases} \qquad (3)$$

where:

R_o = initial detection range in nautical miles
x = uniformly distributed random number between zero and one

Ranges above 20 nm are not considered because of the maximum encounter range of the site at low altitude. This is based upon the output of a TAC ZINGER model of a SAM encounter with similar parameters (Ref 23).

The geometry of the SAM encounter is depicted in Figure 6. Once the initial detection range, R_o, is established, the penetrator's offset distance, y, is determined. The penetrator's offset is assumed uniformly distributed between zero and 15nm (1/2 of the site density). If the offset distance, y, is greater than the initial range of detection, R_o, or if R_o is less than the minimum SAM range, the penetrator escapes with no engagement by the site. However, if R_o is greater than y, then the distance remaining in coverage, x_o, is computed and the penetrator

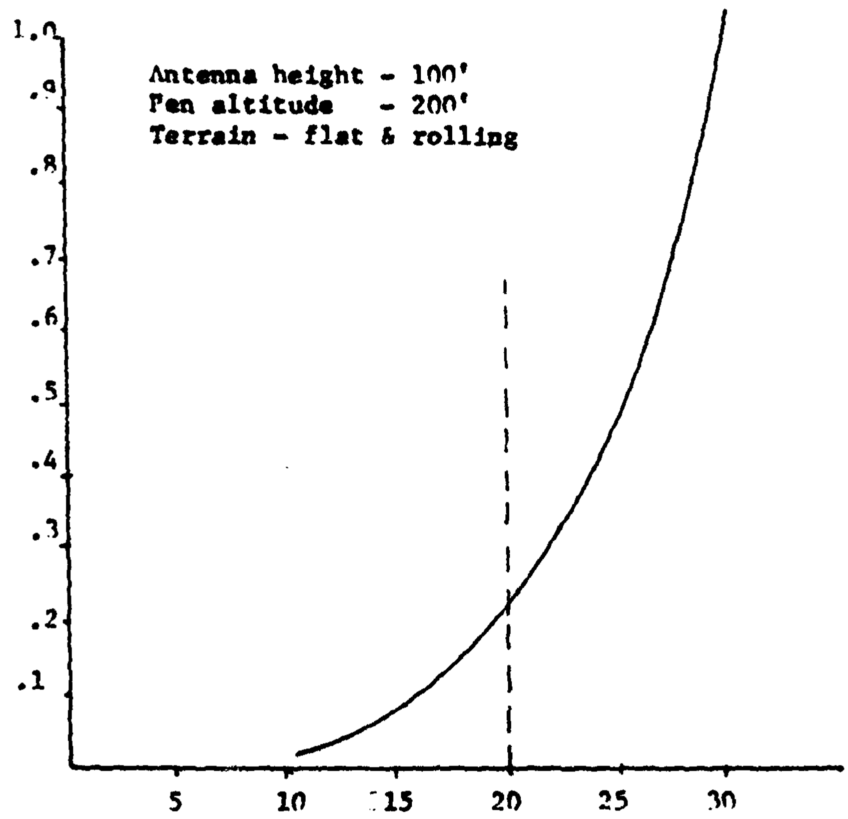


Figure 5. Cumulative Probability of a Penetrator Being Masked As a Function of Range

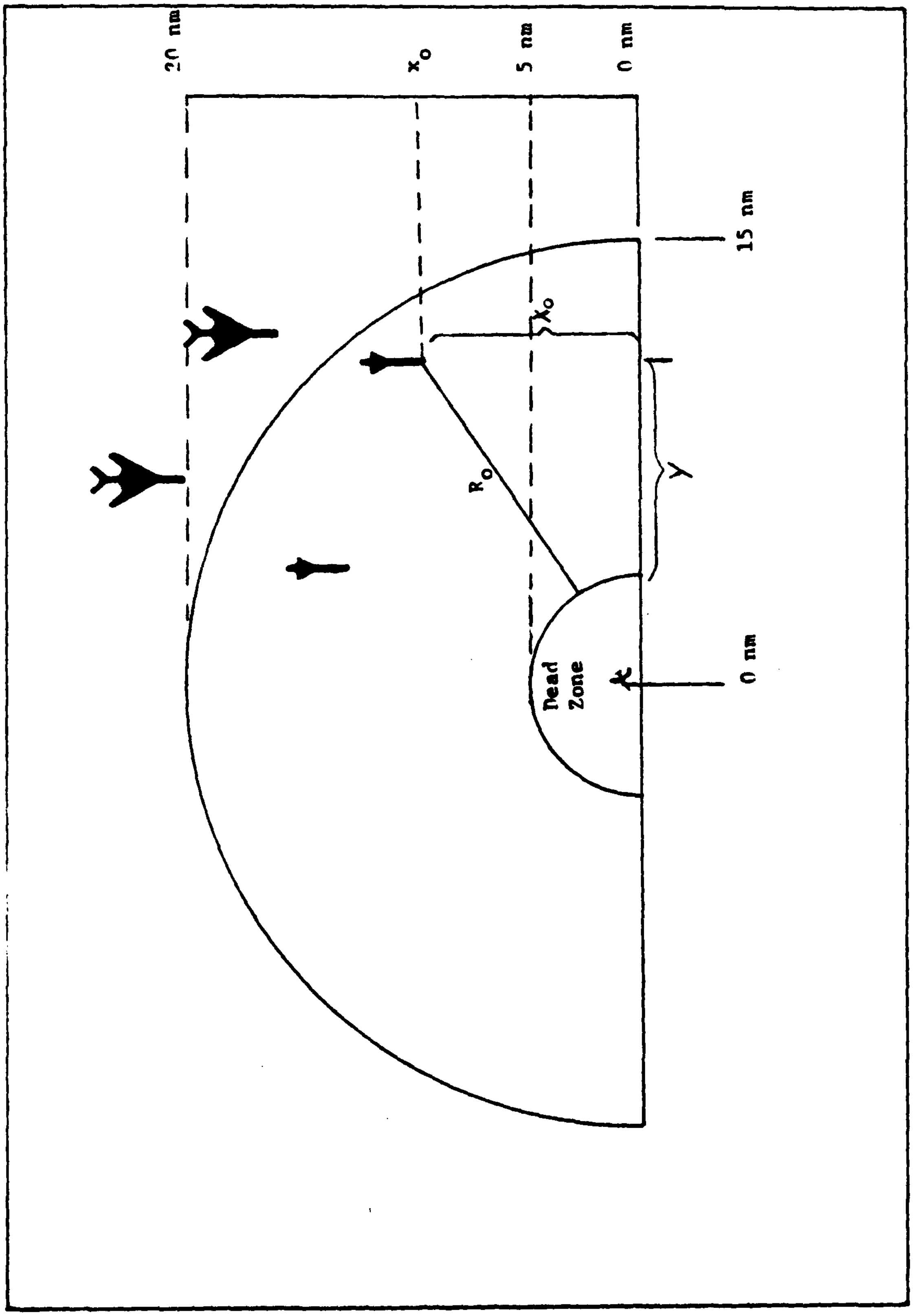


Figure 6 SAM Geometry

is sent to the SAM queue with a time delay of:

$$T = 20. - x_o/V * 60. \tag{4}$$

where:

T = the time from entering the system to initial SAM encounter time in minutes

x_o = initial distance to fly before exiting SAM coverage (nm)

V = penetrator velocity in nautical miles per hour (knots)

The SAM queue priority is lowest value of x_o first. This gives priority to penetrators who are about to exit coverage.

Launcher Assignments. Each launcher is modeled as a resource. Tied to the resource is a global variable which keeps track of the missiles remaining on the launcher. When there is at least one launcher available, a penetrator is drawn from the SAM queue. The penetrator is assigned to the available launcher with the largest amount of missiles remaining.

CEP Determination. Missile miss distance is expressed in terms of missile CEP. It has been shown that missile CEP can be modeled as a function of range and jamming-to-signal noise ratio (J/S) in the presence of jamming. In the absence of jamming, CEP can be modeled as a function of range and signal-to-noise ratio (S/N) (Ref 8). The equation used for the CEP of the SA-X is:

$$CEP = \sqrt{2.42 \times 10^{-8}(J/S)R^2 + 199(J/S) + 624} \quad \text{with jamming} \tag{5}$$

$$CEP = \sqrt{2.42 \times 10^{-8}(N/S)R^2 + 199(N/S) + 624} \quad \text{without jamming} \tag{6}$$

where:

CEP = missile circular error probable in feet
R = range at launch in feet
J/S = jamming to signal noise ratio (dimensionless ratio)
N/S = inverse of the signal to noise ratio (dimensionless ratio)

In order to obtain an expression for the S/N ratio the radar range equation, equation (2), is solved for S/N:

$$S/N = \frac{P_t G_t G_r \lambda^2 N}{(4\pi)^3 k T_o B_t L} * \frac{\sigma}{R^4} \qquad (7)$$

All terms but σ and R are constant. Thus, S/N may be expressed as:

$$S/N = K_a \frac{\sigma}{R^4} \qquad (8)$$

Solving for the constant K_a in equation (8) by substituting the system parameters:

$$K_{a(dB)} = 50dB + 43dB + 40dB + (2 * -16dB) + 18dB$$
$$-(33dB - 144dB + 8dB + 12dB)$$

$$K_{a(dB)} = 210dB$$
$$K_a = \log^{-1} 210/10$$
$$K_a = 10^{21}$$

Thus S/N may be expressed as:

$$S/N = 10^{21} * \frac{\sigma}{R^4} \qquad (9)$$

Thus, missile CEP varies as a function of RCS and range. The S/N ratio is used for computing the missile CEP against the ALCM. The radar cross section of the cruise missile varies as a function of azimuth and is shown in Table 2.

Jamming to signal noise ratio is calculated in the following manner (Ref 15:85):

$$J/S = \frac{P_j G_j B_t (4\pi) L}{P_t G_r B_j N} * \frac{R^2}{\sigma} \qquad (10)$$

Only the bomber aircraft use J/S in calculating missile CEP. The bomber is assumed to carry repeater jammers capable of transmitting 2000 watts (33dB) of Effective Radiated Power (ERP)(Ref 17). The bandwidth must be at least as wide as the bandwidth of the SAM and is presumed to be 1.25 times as wide or 9dB. Again only R and σ are variable. Therefore:

$$J/S = K_b \frac{R^2}{\sigma} \qquad (11)$$

where the constant, K_b, is computed to be:

$$K_{b(dB)} = 33dB + 8dB + 11dB + 12dB - (50dB + 40dB + 9dB + 18dB)$$

$$K_{b(dB)} = -53dB$$

$$K_b = \log^{-1} -53/10$$

$$K_b = 5.01187 \times 10^{-6}$$

Substituting K_b into equation (11):

$$J/S = 5.01187 \times 10^{-6} * \frac{R^2}{\sigma} \qquad (12)$$

Table 2

The following is the RCS values used in DILUTE. RCS groups 1-3 pertain to bomber aircraft and 4-6 pertain to ALCM. Groups 1 and 4 represent hypothetical data for worst case RCS profiles. Subsequent RCS sets are successive 10dB improvements over the worst case. Values are in square meters (m^2).

RCS AZIMUTH	1	2	3	4	5	6
0	18	1.8	.18	.10	.010	.0010
10	16	1.6	.16	.08	.008	.0008
20	15	1.5	.15	.07	.007	.0007
30	14	1.4	.14	.06	.006	.0006
40	12	1.2	.12	.05	.005	.0005
50	20	2.0	.20	.10	.010	.0010
60	35	3.5	.35	1.00	.100	.0100
70	40	4.0	.40	1.30	.130	.0130
80	500	50.0	5.00	6.00	.600	.0600
90	2000	200.0	20.00	25.00	2.500	.2500
100	500	50.0	5.00	6.00	.600	.0600
110	40	4.0	.40	1.30	.130	.0130
120	20	2.0	.20	1.00	.100	.0100
130	50	5.0	.50	.10	.010	.0010
140	90	9.0	.90	.05	.005	.0005
150	55	5.5	.55	.18	.018	.0018
160	45	4.5	.45	.16	.016	.0016
170	60	6.0	.60	.15	.015	.0015
180	90	9.0	.90	.14	.014	.0014

Thus, J/S varies as a function of range and radar cross section. The radar cross sections of the bomber vary as a function of azimuth and are shown in Table 2.

Target Kill. Target vulnerability and SAM warhead fragmentation patterns were used in establishing the lethal radius of the SA-X. Lethal radius (LR) is defined as that miss distance which will result in a 50% probability of kill on a target and, for any particular warhead, varies as a function of target vulnerability. The lethal radii used were (Ref 8):

	Bomber	ALCM
SA-X	135'	70'

The single shot probability of kill (SSPK) of the missile is modeled by the following equation (Ref 8):

$$SSPK = 1 - .5^{(LR/CEP)} \tag{13}$$

This assumes that the missile launch, flyout, fuzing, and detonation work as planned. To account for the probability of missile failure from launch to detonation a reliability factor of .8 (Ref 8) was used. The overall probability of kill (PK) then becomes:

$$PK = (.8) * (1 - .5^{(LR/CEP)}) \tag{14}$$

Engagement. This section describes how CEP and PK given CEP are fit into an operational sequence of events which comprise the SAM/penetrator encounter. Program SAX was developed externally to model the SAM engagement. SAX was then inserted into the user written subroutines of the SLAM programming language.

When the penetrator is pulled from the SAM queue and a launcher assignment is made, a new initial range is computed which is based on the original detection range, speed of the penetrator, and time spent in the SAM queue. This is the point where track attempt is begun. A PK decision rule is used to determine when the launcher should fire its first missile. If the PK check is not passed at the initial range, the penetrator is advanced in 1 nautical mile increments until the PK check is passed. Once the PK is attained the SAM firing sequence begins. Program SAX was excercised numerous times experimenting with different PK decision rules. High PK decision rules caused the SAM to wait until the penetrator azimuth swung to more favorable radar cross sections. Not only did this cause longer engagement times because of the SAM having to wait for relatively long periods, but many times only one shot could be fired. Also for a nose on encounter at low RCS the SAM would never fire. At low PK firing decsion rules the launchers would fire at long ranges with low PKs and exhaust their launcher supply of four missiles rapidly and would have to go "down" for reload. It was observed that the PK increased slowly to about .2 and then would rapidly increase. For these reasons a PK decision rule of .2 was used. This value is set as a variable at the start of the simulation run and may easily be updated for further analysis.

At the start of the firing sequence a lead intercept point is calculated based on a proportional navigation routine (see Figure 7) which is a function of average missile flyout velocity, penetrator velocity, and azimuth. The following equation was used to compute the intercept point (Ref 13:31):

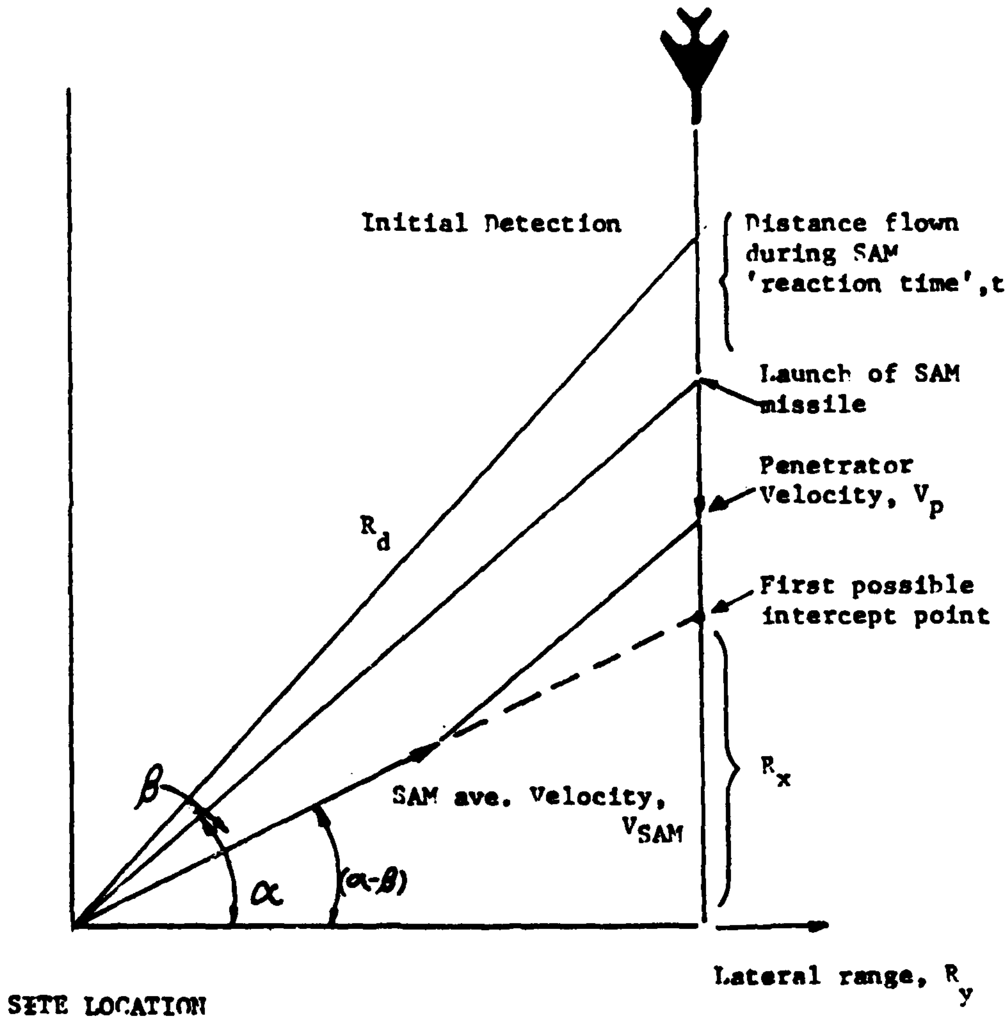


Figure 7. Lead Point Intercept

$$R_x = \begin{cases} V_{SAM} \left[\dfrac{R_d - V_p t}{V_p + V_{SAM}}\right] & \text{for } R_y = 0 \\ R_y \tan(\alpha - \beta) & \text{for } R_y > 0 \end{cases} \tag{15}$$

where:

$$\alpha = \tan^{-1} \frac{(R_d^2 - R_y^2)^{\frac{1}{2}} - V_p t}{R_y} \tag{16}$$

$$\beta = \sin^{-1} \frac{\cos\alpha}{(V_{SAM}/V_p)} \tag{17}$$

where:

V_{SAM} = SAM missile velocity

V_p = penetrator velocity

R_d = detection range

R_y = offset range

t = distance flown by penetrator during SAM reaction time.

Once the point of intercept is calculated, the RCS of the penetrator at missile impact is determined and the missile CEP is calculated based on either a J/S or S/N ratio. The PK is calculated and a uniformly distributed random variable is drawn and compared with the PK. If the random variable is less than the computed PK the penetrator is killed and the encounter terminates. The time elapsed is based on the initial encounter range, the range at time of kill, and the penetrator velocity. If the penetrator is not killed, his position is advanced for the interfire time. If there is still a missile remaining on the launcher and the penetrator is still in coverage, a new lead intercept point is calculated and the process is repeated. This continues until the penetrator is

killed, the launcher runs out of missiles, or the penetrator leaves the coverage.

Once the encounter is over the penetrator goes on one of three paths. Depending on his status, the penetrator either:

1. is eliminated from the system.
2. returns to the SAM queue if he has not reached the boundary of the SAM coverage.
3. goes on to the AI area if he has left the SAM coverage.

The launcher takes one of the following two paths:

1. If there is at least one launcher missile remaining and a penetrator is in the SAM queue, the launcher returns with a minimum time delay to engage the penetrator.
2. If there are no launcher missiles left or if no penetrators are in the queue, the launcher will go down for reload with the reload time being a function of the number of missiles to be loaded.

AI Engagement

Manned interceptor defenses represent a complex system of ground based and airborne components interacting in time and space with an attacking force of penetrators. All successful defense systems must perform a number of consecutive functions to attain their objective of destroying the attacker. These functions are (Ref 14:10):

Early Warning
Target Detection
Threat Verification
Intercept Point Prediction
Interceptor Assignment
Interceptor Vectoring
Target Acquistion by Interceptor
Conversion
Weapon Release
Weapon Lock-on, Flight
Weapon Fuzing/Detonation
Target Kill
Kill Assessment

The probability of a successful encounter is the product of the individual conditional probabilities for each function (assuming statistical independence between events). Manned interceptors typically operate over a wide battle area. A penetrator, therefore, may have several AI engagements on the way to its objective.

Modeling the AI engagement, therefore, can be accomplished by determining the probabilities associated with each defense function and the number of individual attacker/defender encounters. To simplify the analysis, critical defense functions are modeled by the following events:

E1 Detection by GCI
E2 Interceptor Assignment & Vectoring
E3 Interceptor Detection and Conversion
E4 Target Kill

A number of functions are grouped together in the four functions identified above. Initial early warning is presumed to have occured; also

both detection and verification is included in E1. An interceptor is assigned (if available) and vectoring is accomplished with an error term that is normally distributed with a mean of zero and standard deviation of three nautical miles. E3 includes target acquistion and convergence by the fighter into a proper engagement envelope. Weapon release, lock-on, flight, fuzing, detonation, and kill is included in E4. The AI employs a shoot-look-shoot strategy with no error in target kill assessment. The following sections describe the modeling of these events.

Detection. The detection of a penetrator by the EW/GCI components of a defense system requires that the radar have sufficient sensitivity and subclutter visibility and that the penetrator not be masked by terrain features. As previously discussed in the SAM engagement section, the EW/GCI radars will not be considered power limited and are postulated to have sufficient subclutter visibility to reliably detect and track the penetrators. Thus the limiting factor on detection will be the line-of-sight (LOS) range.

The same terrain model and masking probabilities are assumed for the AI encounter as for the SAM encounter. A "cookie cutter" approach is used in determining the effective radius of the GCI site. The effective radius is defined as that radius, given the type of terrain, penetrator altitude, and antenna height, at which there is a 50% or greater chance of obtaining a LOS. All penetrators that are further than this distance from the site are considered masked, while all penetrators that come within this radius will be considered detected. As seen from Figure 5, for a 200' penetrator against a radar with 100' antenna in flat and rolling terrain, the 50% detection range is estimated at 25nm.

By knowing the site density, ρ, and the effective radius of the site one can find the expected number of encounters in a distance, D (Ref 18:173):

$$E(N) = \rho * 2R * D \tag{18}$$

where:

$E(N)$ = expected value of the random variable, N, the number of encounters

ρ = site density in sites/nm^2

$2R$ = two times the effective radius of the site (diameter)

D = total distance remaining in area

It is assumed that the threat environment is such that the penetrators encounter radars as if no avoidance were practiced and the radars are Poisson distributed in the plane. This assumption was used in the FIOPS (Fighter Interceptor Operations Model) developed for the Air Force by General Research Corporation (Ref 19:6-7) and is substantiated for certain geographic locales (Ref 20).

Let D represent the total distance traveled in the fighter interceptor area. The time in the area is expressed by:

$$T = D/V * 60. \tag{19}$$

where:

T = time in AI area in minutes
D = distance to travel in AI area in nautical miles (nm)
V = penetrator velocity in knots (nautical miles per hour)

Thus the expected number of encounters per minute is:

$$E(N) = \rho * 2R * D/T \tag{20}$$

Substituting for T using equation (19):

$$E(N) = \rho * 2R * V/60. \tag{21}$$

If the number of encounters per minute is Poisson distributed, it can be shown (Ref 21:157) that the time between encounters is exponentially distributed with mean:

$$\lambda = 1/E(N)$$
$$\lambda = 60/\rho * 2R * V \tag{22}$$

<u>Assignment & Vectoring</u>. A confirmed detection and track by a GCI radar starts a chain of events designed to end with the destruction of the penetrator. The GCI site must predict the penetrator flight profile, request a fighter to pursue the penetrator, and then vector the interceptor to the vicinity of the penetrator.

It is assumed that all fighter bases had ample warning of the ensuing battle and all fighters begin the battle from a Combat Air Patrol (CAP) posture. Conceptually, the CAP is split into two CAPs with CAP1 holding those fighters who have expended half their ordinance and CAP2 holding those fighters with a full weapon load. It is presumed that the fighters in CAP1 are the lowest on fuel and are given priority for assignment over those in CAP2. Because of the CAP selection rule used and the short time span of the battle (approximately 75 minutes) no attempt was made to track the fuel remaining of each fighter.

The dominant parameter governing vectoring performance is the arrival time of the interceptor. The time necessary for the fighter to converge to the intercept point will determine whether or not the penetrator will still be within the effective radius of the GCI coverage. The time of fighter arrival depends upon CAP dispersal doctrine, and fighter performance.

A fighter returns to base when his ammunition is exhausted. After rearming and refueling, the fighter launches and becomes part of CAP2. Given the short duration of the battle this portion of the model plays a very minor role. The main contribution of this portion of the model to the overall modeling effort is that it adds flexibility if the model is to be expanded.

For the purposes of this study, interceptor arrival time is modeled by a random variable, uniformly distributed between 200 and 400 seconds. Fighter return, service, and launch time is modeled by a random variable, uniformly distributed between 47 minutes and 57 minutes. It is felt that these figures represent worst case (for the offense) situations. While these are not precise measurements, they capture the relative order of magnitude necessary for the level of detail presented in this study. Further details as to Soviet doctrine, fighter performance, basing, and maintenance capabilities would classify this thesis.

Detection & Conversion. After the GCI system has vectored the AI to the vicinity of the penetrator, the interceptor must then detect the penetrator and convert to a position within the envelope of its weapons. The probability of a successful detection and conversion given a success-

ful vectoring is termed Probability of Detection and Conversion (PDC). PDC is functionally related to the quality of the AI radar, the heading conversion angle (HCA), and the penetrator's radar cross section (RCS).

Tight GCI control generally demands that loss of target track by the GCI radar ends the engagement. However, low altitude penetrators traverse regions of GCI coverage in such a short time that requiring the penetrator to be within GCI coverage at AI arrival would unrealistically restrict the defense. Therefore, it is reasonable to assume that the GCI system would extrapolate the track of the penetrator for a modest time after leaving the site coverage. This greatly increases the uncertaintly volume of space that the AI must search for the penetrator and, thus, decreases the PDC. This leads to a concept of two PDC's; one for an AI intercept within coverage, PDC_{in}, and one for out of coverage, PDC_{out}. Figure 8 represents the concept of in-coverage and out-of-coverage. The radar coverage circle is for a 200' penetrator and the circle size increases for increasing penetrator altitude.

The PDC values used were extracted from a PACAM model (Ref 32) which was run using a Class II type fighter. Table 3 shows the PDC values as a function of RCS, and HCA. RCS levels are coded RCS groups as described in Table 2. Random intercept headings are presumed so the average of all HCA's within an RCS group was used in the model to determine the PDC.

An average in-coverage track length is used in computing the time under radar coverage. It is assumed that the offset distance that the penetrator crosses to the GCI site is random. Therefore the average offset distance would be one half the effective radius:

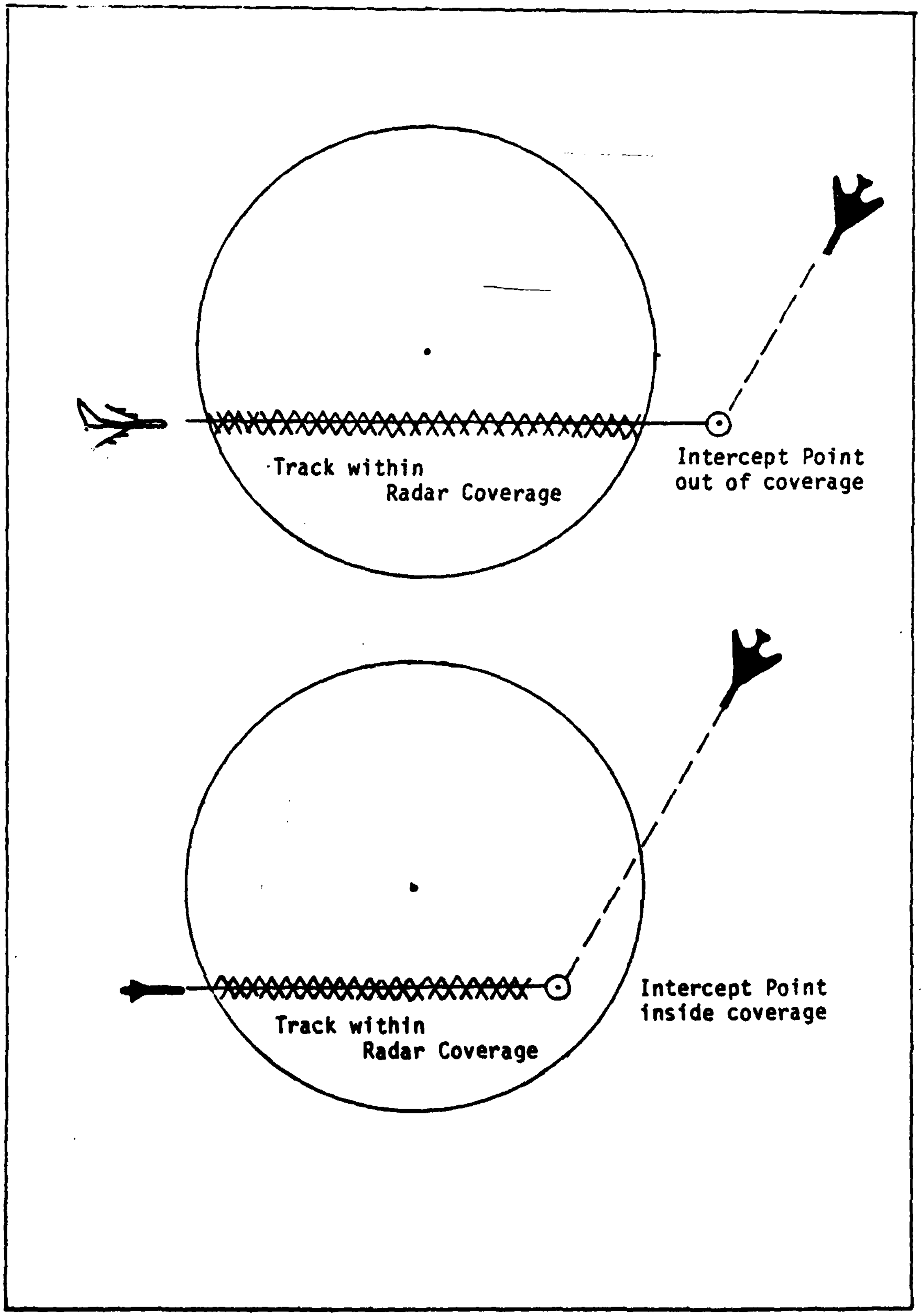
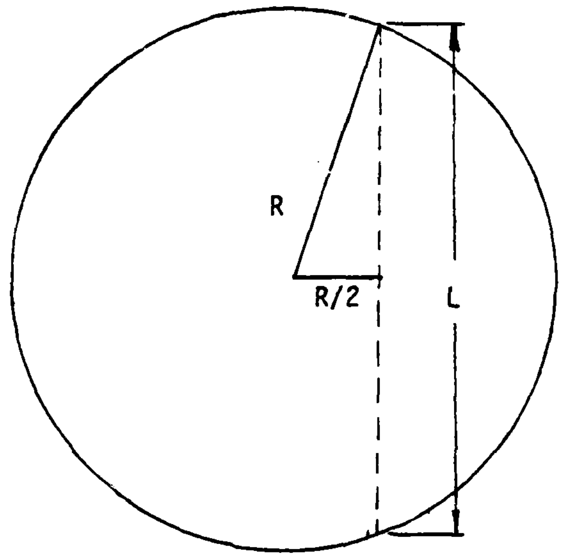


Figure 8 - Radar Coverage Diagram

Table 3

PROBABILITY OF DETECTION & CONVERSION

RCS / HCA	IN COVERAGE (PDC_{in}) 1	2	3	4	5	6	OUTSIDE COVERAGE (PDC_{out}) 1	2	3	4	5	6
0	1.	1.	.931	.030	0	0	.666	.666	.301	.002	0	0
30	.454	.454	.398	.006	0	0	.457	.229	.073	0	0	0
60	.850	.685	.304	.005	0	0	.771	.633	.509	.282	.089	.005
90	1.	1.	1.	.984	.769	.135	.863	.833	.667	.416	.216	.047
120	1.	1.	1.	1.	.892	.161	1.	.985	.672	.480	.237	.051
150	1.	1.	1.	1.	.900	.122	1.	.971	.669	.499	.266	.054
180	1.	1.	1.	1.	.895	.144	1.	.964	.667	.503	.274	.021
AVE	.900	.877	.804	.575	.494	.080	.822	.754	.508	.312	.155	.025



The total track length, L, is:

$$L = 2\sqrt{R^2 - R^2/4}$$

$$L = 2\sqrt{R^2(1 - \tfrac{1}{4})}$$

$$L = 2R\sqrt{.75}$$

$$L = 1.732\ R \qquad (23)$$

Electronic Countermeasures (ECM) used by the bomber complicates the defense's problem of performing a successful intercept. It has been shown (Ref 22:353) that the probability of a successful AI engagement against a bomber decreases approximately 30% in the presence of ECM. Thus an ECM effectiveness factor of .7 was used in reducing the PDC for a bomber penetrator.

An unsuccessful conversion results in the fighter being tied up for a length of time equal to his flying time to the intercept point. A

successful conversion results in shots fired at the penetrator. The interceptor fires until the penetrator is killed, or the interceptor runs out of missiles. The interceptor will break off the attack if during the attack, the penetrator enters the TSAM zone (a one minute flying time overlap is allowed).

Each fighter starts out with four missiles. The fighter fires two at a time. Thus each fighter may shoot two volleys of two missiles each. If a fighter reaches a kill envelope on either a cruise missile or bomber and launches a missile against the penetrator it is presumed that if the missile works properly, it will kill with a probability of 1.0. However, factored into the Single Shot Probability of Kill (SSPK) will be the probability of a successful missile launch, flyout, fuzing, and detonation. Thus a SSPK of .8 was used as representative of missile reliability (Ref 23). The overall PK of a volley of two then may be computed as follows:

$$PK = 1 - (1 - SSPK)^2 \qquad (24)$$

$$Pk = .96$$

Thus, if a fighter converges on a penetrator, the PK used in the model is .96 for each volley.

After the engagement, the fighter is placed either in CAP1, or CAP2, or returns to base depending upon the status of his weapons. If the penetrator survives, the time of the next encounter is drawn from an exponential distribution with a mean computed based on the number of GCI sites remaining in the system. If the time of the next engagement exceeds the penetrator's planned time to enter the TSAM, then the penetra-

tor proceeds to the TSAM. If the time of the next encounter is less than the time to enter the TSAM, then the penetrator is routed back to the AI queue with a time delay as computed from the exponential distribution using the current number of GCI sites to determine the mean time between encounters as previously described.

Value Average Probability of Damage (VAPD). The term Value Average Probability of Damage (VAPD) was developed as the primary measure of effectiveness (MOE) in evaluating the weapon systems. Conceptually, VAPD measures the proportion of value destroyed for the entire target base. Two hundred target values are stored in arrays Z1, Z2, Z3, and Z4 representing the four target zones. These arrays are initialized by a data statement at the beginning of each simulation run. When a penetrator reaches the target or SRAM launchpoint, a weapon miss distance is generated. Then, based upon the miss distance, yield, height of burst (HOB), and target damage response, the individual target's value is updated within the arrays by the following recursive algorithm:

$$V_{ij} = V_{ij-1} - PD_{ij}V_{ij-1} \qquad \begin{array}{l} i = 1 \text{ to } N \\ j = 1 \text{ to } n_i \end{array} \tag{25}$$

where:

V_{ij} = the value remaining of the i^{th} target after the j^{th} weapon has struck

V_{ij-1} = the value remaining of the i^{th} target prior to the j^{th} weapon strike

PD_{ij} = probability of damage to the i^{th} target by the j^{th} weapon

N = total number of targets in the target base

n_i = number of weapons allocated to the i^{th} target

For each weapon impact the value extracted is the product of PD_{ij} and V_{ij-1}. For all targets the variable VAPD is summed in the following manner:

$$\sum_{i=1}^{N} \sum_{j=1}^{n_i} PD_{ij} V_{ij-1} \tag{26}$$

In this study N=200, and n_i=2 for all i.

The probability of damaging the target is a function of the weapon miss distance, yield, height of burst (HOB), and target vulnerability. The following table shows the weapon systems' characteristics used in this study. Actual figures are not used because of security restrictions. However, these values capture the order of magnitude necessary for relative comparisons:

	# wpns ea	Yield	CEP	HOB
Bomber				
Gravity	4	1000 KT	1000ft	0ft
SRAM	6	200 KT	800ft	4000ft
ALCM	1	200 KT	400ft	4000ft

The following subsections show the methodology used in computing the damage probability.

Target Vulnerability. A representative hardness level for structures found in urban/industrial areas was selected as one with a Vulnerability Number (VN) of 13Q7 from the DIA Greenbook. The following discussion is taken from unclassified sections of the Greenbook (Ref 24:I-2). The Q in the VN number classifies the target's primary damaging mechan-

ism as peak dynamic overpressure, q. The first two digits of the VN number are generated from an artificial numerical scale which associates damage probabilities with peak dynamic overpressure required from a 20KT weapon to achieve a .5 probability of severe damage to a randomly oriented target. For a target with a VN of 13Q7, the first two digits were computed by the following equation:

$$6.31 (\log q_{.5}) + 9.72 = 13 \tag{27}$$

Where $q_{.5}$ is the peak dynamic overpressure associated with a .5 probability of damage. Solving for $q_{.5}$:

$$q_{.5} = \log^{-1} .5198$$
$$q_{.5} = 3.3$$

However nuclear effects calculations are usually available for peak overpressure (Δp) and not peak dynamic overpressure, q. To find q as a function of Δp necessitates solving a series of partial differential equations (commonly called the Rankine-Hugoneot equations) which describe blast wave phenomena across the shock front. From this derivation it can be shown that (Ref 25):

$$q = \frac{5(\Delta p)^2}{2((7)(14.7) + \Delta p)} \tag{28}$$

This applies for sea level standard day conditions. Then solving this quadratic equation for Δp when q = 3.3, yields a Δp = 12.333 . This then is the overpressure required to create a peak dynamic overpressure

of 3.3 psi for a 20 KT burst at sea level.

The second portion of the VN number is called the K factor. An adjustment to Δp for the K factor is necessary because the pressure required to damage a target varies as a function of yield (Ref 24:I-2). This is because the actual damage on target is a function of the force on the target and the time duration of the force. This functional relationship is called Impulse (I) which is the time integral of force acting on the target:

$$I = \int_{t_a}^{t_b} q(t)dt \tag{29}$$

where $t_a - t_b$ is the time of the positive phase duration of the force. In general, the larger the yield, the longer is this time duration and consequently the lower the force necessary to give a specified impulse. The mean overpressure kill criteria ($\Delta p_{.5}$) was, therefore, adjusted for the K factor (Ref 24:I-33) for each class of weapon and is shown below:

Gravity bomb	8 psi
SRAM	9 psi
ALCM	9 psi

<u>Miss Distance Generation</u>. Hit patterns are assumed to be bivariate normal distributions (Ref 26:98). The bivariate normal with a mean of zero is shown below:

$$f(x,y) = \frac{1}{2\pi\sigma_x\sigma_y} \text{EXP}-\tfrac{1}{2}[(x/\sigma_x)^2 + (y/\sigma_y)^2] \tag{30}$$

In this equation σ_x is the downrange standard deviation and σ_y is the cross range standard deviation. Aircraft hit patterns tend to follow an elliptical distribution with the major axis down range (Ref 26:101). This implies that $\sigma_x > \sigma_y$. From the authors' personal experience it seems that in general $\sigma_x = 2\sigma_y$. Each miss distance for the ALCM and the bomber gravity weapons were generated in the FORTRAN subroutines by a call to two normal distributions each with a zero mean and standard deviations from the stated CEPs of each weapon. The SRAM delivery profile was assumed to be semi-ballistic in order to attain maximum range. This profile results in steep reentry angles. Due to the relatively short distances involved and the steep reentry angle, the SRAM hit pattern was modeled by a circular normal distribution with $\sigma_x = \sigma_y$. Appendix D shows how σ_x and σ_y were derived from the CEP.

Overpressure Calculation. The overpressure that the target experiences is a function of the miss distance, yield, and height of burst (HOB). An air burst enhances the overpressure effect on ground targets. When the blast wave from an airburst strikes the ground it is reflected back, similar to a sound wave producing an echo. At a certain region on the ground the original wave front and the reflected wave front merge. This phenomenon is called the "Mach front". Overpressures in this Mach front are generally twice as great as that at the original blast wave front (Ref 27;38). The position of this Mach wave depends mainly on the weapon yield and height of burst. The Mach effect is the reason for the characteristic "knee" shape of the curves in Figure 9. Figure 9 depicts overpressure on the ground as a function of height of burst and miss distance for a 1KT burst.

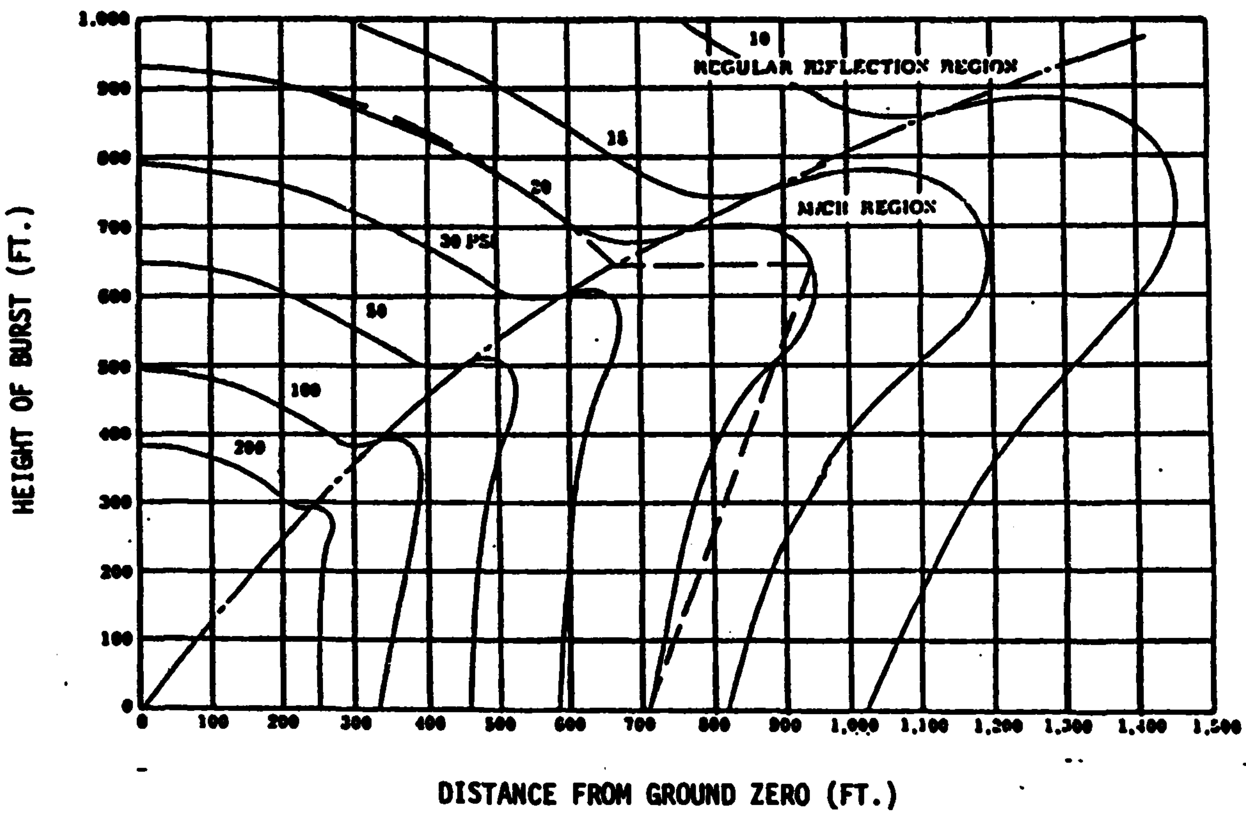


Figure 9. Peak Overpressures on the Ground for a 1-Kiloton Burst (Medium-Pressure Range)(Ref 27)

Height of burst was optimized by selecting the applicable overpressure of concern (10 psi) and then selecting the height of burst which maximized the distance from ground zero at which the desired overpressure effect is observed. For 10 psi an altitude of 710' was chosen. This is called the "scaled" height of burst (SHOB).

The miss distances on the horizontal axis of Figure 9 are called "scaled" miss distances because they pertain to a 1KT burst. If the yield of the weapon differs from the 1KT reference, one must "scale" the actual miss distance to the 1KT reference case. This is done via the following scaling law (Ref 27:112):

$$\frac{R}{R_{1KT}} = \frac{W}{1KT}^{1/3} \tag{31}$$

where:

R = actual miss distance

R_{1KT} = 1KT reference miss distance

W = weapon yield in KT (kilotons)

This scaled miss distance and the scaled HOB are the entering arguments for computing the overpressure at the target. The curve fit to Figure 9 is quite lengthy and is contained in Appendix E.

<u>Damage Function</u>. The probability of damage, PD, is described as a random variable following a lognormal damage function of the form (Ref 25):

$$PD(\Delta p) = \int_0^{\Delta p} \frac{1}{\sqrt{2\pi}\beta x} \text{EXP} -\tfrac{1}{2} \left[\frac{\ln(x) - \alpha}{\beta}\right] dx \tag{32}$$

where:

Δp = overpressure resulting from a given miss distance

$\alpha = \ln(\Delta p_{.5})$

β = the standard deviation of the underlying normal distribution

Assuming a "Sigma-30" type target implies (Ref 24:IV-1):

$$\frac{\Delta p_{.69} - \Delta p_{.31}}{\Delta p_{.50}} = .30 \tag{33}$$

where Δp_x is the overpressure at which the probability of damage is x. Using equation (33) along with the identities:

$$\frac{\ln\Delta p_{.69} - \ln\Delta p_{.50}}{\beta} = .5 \tag{34}$$

$$\frac{\ln\Delta p_{.31} - \ln\Delta p_{.50}}{\beta} = -.5 \tag{35}$$

where $\Delta p_{.50}$ is 8 psi or 9 psi depending upon the weapon yield. Solving these three equations (33,34, and 35) with three unknowns:

$$\begin{array}{rll} \Delta p_{.50} = & 8 & 9 \\ \Delta p_{.69} = & 9.29 & 10.45 \\ \Delta p_{.31} = & 6.89 & 7.76 \\ \beta = & .2979 & .2988 \end{array}$$

The parameter β was set equal to .30 for all weapons.

To summarize, the parameters used in the lognormal damage function were:

Gravity weapon	SRAM & ALCM
$\alpha = \ln(8 \text{ psi})$	$\alpha = \ln(9 \text{ psi})$
$\beta = .30$	$\beta = .30$

In summary, this chapter presented the main concepts of the model DILUTE. These main concepts were structured in blocks. The blocks were: Arrival Rates, Target Assignments, SAM encounter, AI encounter, Target Damage. Each block was discussed and the underlying mathematical relationships and logic flow was presented. The next chapter discusses how these blocks were dovetailed into the SLAM network simulation language.

III. Computerization

This chapter provides a detailed description of the major aspects of the penetration model. The sections to be covered will begin with the Initialization routine followed by the generation of Penetrator Arrivals, the Target Assignments, the BSAM Encounter, the AI Encounter, the Terminal SAM Encounter, and the Output Subroutine. Finally the chapter closes with a summary.

The penetration model uses the SLAM network shown in Appendix A. In general, the network routes penetrators through three independent tiers of defenses (BSAM, AI, and TSAM) ultimately sending each penetrator to either a "kill" node if it is shot down, or a "survive" node if it successfully negotiates the defensive arrays. The network and subroutines will be discussed in the order stated above.

Initialization Subroutine (INTLC)

Prior to the start of the network an initialization subroutine called subroutine INTLC, a user-written subroutine, is called by SLAM before each simulation run to set the initial start-up conditions of the model. These initial start-up conditions are variables that can either be fixed or variable and are user dependent. SLAM uses an array called XX(I) which is a single dimension array for storage of these global variables that are common throughout the network. These variables can be set in one portion of the network and then used in any other portion of the network. The global variables that are set for the initial start-up conditions can be found in lines 18 through 157 of the FORTRAN code (Appendix C). The creation and generation of the penetrators will now be discussed.

Penetrator Arrivals

The simulation begins with the generation of Bombers and ALCMs entering penetration corridor #1 and corridor #2. The bomber arrivals are generated from a lognormal distribution, and ALCM arrivals are generated from a normal distribution. The selection of these distributions was explained in Chapter II. For the remainder of this study penetration corridor #1 will be used to describe the network structure, however, it should be noted that penetration corridor #2 network structure operates and functionally behaves as corridor #1. The ensuing discussion will focus on corridor #1 beginning with the assigning of attributes to the penetrators (entities).

ASSIGN Nodes (ASN1 through ASN8)

The ASSIGN node is used to prescribe values to the attributes of an entity passing through the ASSIGN node or to prescribe values to global variables that pertain to the network in general. SLAM uses an array called ATRIB(I) which is a single dimension array for storage of attribute values that are tagged with each entity. A description of the ASSIGN node ASN1 is shown below and can be found in lines 64 and 65 of the SLAM computer code (Appendix B).

Atributes	Description
ATRIB(1) = 1	Indicates that the entity is a bomber
ATRIB(2) = XX(3)	Sets the speed of the bomber
ATRIB(3) = XX(4)	Sets the RCS group of the bomber
ATRIB(4) = XX(5)	Sets the bomber altitude
ATRIB(11)= 1	Initial target zone assignment
ATRIB(15)= 1	Corridor number

A complete description of all the attributes used within the model can be found in Appendix F. Once the penetrators are generated and assigned attributes they enter the target assignment algorithm.

Target Assignments

The target assignments are represented by Event nodes 9 and 10. Event node 9, labeled as TGT1 in the network, calls subroutine 9 which sequentially assigns bombers to their individual targets within Zones 2, 3, and 4. Event node 10, labeled as TGT2 in the network, calls subroutine 10 which sequentially assigns ALCMs to their individual targets within Zones 1 through 4. The target assignments are then stored in Attributes 21 through 24 which represent Zones 1 through 4 respectively. A complete description of the target assignment algorithms can be found in lines 930 through 952 of the FORTRAN code contained in Appendix C. The next section will discuss the penetrator's encounter with the first tier of defense, the Band SAM (BSAM).

BSAM Encounter

Once the target assignments are made, the penetrators continue down their respective corridors until being detected by a BSAM. As stated previously, the BSAM is representative of the first tier of defense a penetrator can expect to encounter in-country. Quite extensive network development was necessary to effectively capture the one-on-one encounter between a SAM and a penetrator. The computerization not only adds credibility to the model, but also captures the realism of a SAM encounter. The actual SAM encounters are incorporated in a series of USERF written functions which employ FORTRAN coding. By using the USERF

functions all the elements of a SAM encounter could be determined and set within the model. A brief description of USERF functions is now in order.

USERF(1) (Appendix C, lines 173 through 207) determines the detection range, ATRIB(17), time to fly to SAM envelope encounter, ATRIB(6), time to exit the SAM coverage, ATRIB(8), probabilistically determines if the penetrator is detected or not, and if detected is sent to the SAM queue indicated as SAM1 in the network. At the same time a clock is started with a duration time equal to the entity's time in SAM coverage. This is accomplished by routing an entity through Activity number nine (see Appendix A). If the entity is not engaged by the time the clock runs out (completion of Activity number nine), Subroutine 11 is called which removes the penetrator from the SAM queue. However, if the penetrator is engaged he is first routed to Event node 3 which calls Subroutine 3. Subroutine 3 "stops the clock" by removing the "clock entity" from the event calendar.

A launcher assignment algorithm, USERF(12), is then called to select from those launchers available the launcher with the largest supply of missiles remaining. See Appendix C lines 519 through 539. Once the launcher is selected, the site will have an opportunity to engage the penetrator.

The actual engagement of the penetrator is now handed off to USERF(4) (Appendix C, lines 248 through 390). USERF(4) is a mini-simulation of the SAM encounter which computes the point of first missile fire, checks to see if the penetrator is an ALCM or a bomber and computes the S/N or J/S ratio respectively. Actual kills are Monte Carloed and compared

against the Probability of Kill (PK) computed as a function of range and J/S or S/N. The SAM tracks the penetrator until a minimum PK value of .2 is attained, at which time the site may fire a missile. Missile sites which are allowed to engage the penetrators are then tied up and placed on the event calendar; they are released once the encounter has terminated. If there is at least one missile left and there is a penetrator in the SAM queue, then the SAM will engage another penetrator. If there are no missiles or there are no penetrators waiting in the queue, the launcher reloads as determined in USERF(2) (Appendix C, lines 210 through 233). USERF(2) computes the SAM reload times, the stockpile of missiles remaining, and the number of missiles left on the launcher. If it is determined that a SAM site's entire missile supply is exhausted, follow-on penetrators will pass through the SAM site coverage and are never engaged by that site. If there is no kill, USERF(4) will calculate a new position based on a three second interfire time and will commence firing another missile. This procedure continues until the penetrator is killed, leaves coverage, or the launcher is out of missiles. The priority given to penetrators waiting in the queue is given to the penetrator with the least distance remaining in SAM coverage. If the penetrator is killed, ATRIB(5), the status variable, is set equal to one and the penetrator's entity is sent to a collect node which gathers applicable statistics on the entity. If the penetrator is not killed, the time out of coverage, ATRIB(8), is checked to determine whether the penetrator is routed back to the next available SAM channel for a second encounter or exits the area for the fighter area.

The second tier of defenses a penetrator can expect to encounter is the fighter interceptor threat (AI) which will be discussed next.

Airborne Interceptor Threat (AI)

Surviving penetrators from the BSAMs enter the fighter resource node designated as FCAP. FCAP is divided into two groups of fighters, CAP1 and CAP2. USERF(13) (Appendix C, lines 542 through 552) assigns the penetrator to either CAP1 or CAP2. In CAP1 are those fighters who have only half of their missiles remaining and are presumed to be shorter on fuel than those fighters in CAP2 which have a full weapon load. The CAP1 fighters are given priority over those in CAP2 for the penetrator engagement.

After CAP selection is determined, USERF(10) (Appendix C, lines 451 through 506) is called to generate the following events: (1) the fighter tie-up time, (2) the fighter arrival time, (3) the number of missiles remaining, ATRIB(16), (4) the kill/no kill probabilities, and the probability of detection and conversion, PDC, for "in" and "out" of coverage. A confirmed detection of a penetrator by a GCI radar initiates USERF(10) which eventually leads to either a kill or no kill condition for the penetrator.

If the interceptor passes the PDC check, it advances to the end-game (missile firing) position where a probability of kill check is made. If the PK check passes, the status variable, ATRIB(5), is set to one for a kill and the corresponding entity is sent to either a Bomber or ALCM collect node which gathers statistics on the entity. If the penetrator is not killed, the penetrator's out of coverage time, ATRIB(14) is checked to determine whether the penetrator is routed back to the FCAP queue, or exits the area for the Terminal SAM (TSAM). If the penetrator survives, and sufficient time remains for a second encounter,

the time of the next encounter will be determined by USERF(8) (Appendix C, lines 427 through 437). USERF(8) determines the time to the next GCI detection by using an exponential distribution with a mean based on XX(45), the "cookie cutter" radius of the site and XX(26), the number of GCI sites remaining in the system. If the time of the next encounter, ATRIB(9), exceeds the penetrators planned time to enter the TSAM, ATRIB(14), then the penetrator proceeds to the TSAM. Otherwise, if ATRIB(9) is less than ATRIB(14), then the penetrator is routed back to the AI queue with a time delay determined in USERF(8).

After an engagement, a fighter with missiles remaining is returned to either CAP1 or CAP2. A fighter that runs out of missiles proceeds to node MSLO and calls USERF(14) (Appendix C, lines 555 through 560). USERF(14) computes the fighter turn-around times based on a uniformly distributed flying time to return to base (RTB). It also determines the ground turn time to reload, refuel, and rearm.

The third and final tier of defense is the Terminal SAM which will be discussed next.

Terminal SAM (TSAM)

Penetrators that have survived the AI threat now enter the Terminal zones designated as TMZN in the network. At the TMZN node, the penetrators are branched according to ATRIB(15), the corridor status variable, and ATRIB(11), the zone status variable. It should be noted that bombers do not penetrate target Zones 2 or 3, but the bombers do launch SRAM missiles from a "safe" distance of the SAM envelope. Bombers then proceed on to target Zone 4 and attempt to penetrate the defense. In the terminal area there are a total of 18 launchers protecting Zones 2, 3,

and 4.

Within corridor #1 of the terminal area there are three SAM sites, two of which have three launchers each, and the third site protecting Zone 4 has six launchers because it has twice as many targets to defend. The same modeling strategies that were used for the BSAM are also used for the TSAM. In other words, the detection process is determined in USERF(1) and the SAM engagement process is determined in USERF(4) as previously described. The TSAM network description can be found in lines 320 through 720 in Appendix B.

Subroutine 8

All bombers and only surviving ALCMs are sent to Subroutine 8 (Appendix C, lines 805 through 930) labeled as Event node ZZ in the network. This subroutine determines the amount of targets the penetrators attack based on when they exit the area. For example, if the penetrator is a bomber and is not killed, Subroutine 8 allows him six SRAM and three gravity weapon releases. If the bomber had been killed, the time of the kill is checked against the scheduled SRAM launch times and, based on the time of the kill, the bomber may release up to six SRAMs depending upon the depth of penetration.

Subroutine 2

Subroutine 2 (Appendix C, lines 686 through 775) is used in determining the VAPD and PD calculations which are a function of weapons delivered. This subroutine computes and updates the VAPD variable, XX(25), for targets struck in Zone 1. In addition, it determines the kill/no kill status for the EW/GCI sites and resets XX(26), which is the number

of EW/GCI sites remaining. Finally, it determines the amount of target value remaining on a target and stores the updated value in a targeting matrix. See Appendix C lines 686 through 775 for a more detailed look at this subroutine.

Subroutine OTPUT

Subroutine OTPUT, a user-written subroutine, is called at the end of each simulation run and is used for formatting the model output. Within Subroutine OTPUT there are three header subroutines which are called to provide a format of the response variables. A complete listing of Subroutine OTPUT can be found in Appendix C, lines 1021 through 1361. An example of a simulation run output is shown in Appendix G.

The computer simulation model described in this chapter allows for a number of factors to be varied. The specific factors used in the sensitivity analysis, and the manner in which these factors were allowed to vary and interact are described in the next chapter.

IV. Experimental Design

The design used in this simulation study was approached in a three step process outlined below and proposed by Shannon (Ref 28:150).

1. Structural Model - the structural model is described by and is a function of the number of factors (independent variables) and the number of levels of each factor.

2. Functional Model - the functional model determines whether all combinations of factors and levels will be studied (full factorial design) or whether only certain combinations will be examined (fractional factorial design).

3. Experimental Model - this is the final step in the synthesis phase of experimental design. This model determines the actual statistical approach to used, and the actual levels of the factors to be studied.

This chapter will explain the three step systematic approach stated above and will explain the statistical procedure selected in analyzing the results of the model.

Structural Model

As stated earlier, the structural model consists of the number of factors and the number of levels of each factor. The factors are the independent variables which are to be controlled by the experimenter. Several considerations were necessary in determining the number and identity of the factors to be used. By reviewing the objectives from Chapter I one can determine the control and response variables. The control variables selected were: force mix, speed, and radar cross section (RCS). The response variables are those variables that represent the model output and were determined to be VAPD and probability of survival of the bomber (PSB).

The next step in designing the structural model was to describe the levels at which each selected factor should be measured. It was desired to examine the response variables over a wide spectrum of possible factor levels. In order to accomplish this, the factors RCS and speed were each set at three levels. In order to capture the entire spectrum of changes in the response variables due to force mix, the force mix factor was set at five levels.

Functional Model

In order to meet the objectives of this study, it was desired that all interaction effects between the factors be examined. Therefore a full factorial design was chosen as the functional model for this experiment. A full factorial design means that all levels of each factor are to be "crossed" with all levels of the other factors.

In order to determine the number of replications (or sample size) required for each combination of factor levels, the approach presented by Shannon (Ref 28:188-189) was used.

Sample Size Determination. First, since the variance, σ^2, was unknown, it was necessary to run a trial experiment to obtain an estimate of the variance (s^2) and from this, the required number of observations could be determined. In this study a trial experiment of 60 simulation runs was used to estimate the population variance. To reduce the overall variance, a stratified sampling plan was used. Using a stratified sampling plan means segmenting the observations into subsets; each subset is then sampled separately and the results are combined into a single estimate. For example, the 60 runs were divided into 6 samples of 10 replications with each sample corresponding to a unique set of

factor levels. The ultimate solution is for the elements within the groups to be more homogenous (having less variation) than the elements in the population as a whole.

The second step is to establish accuracy requirements for the response variable. The response variable used was Value Averaged Probability of Damage (VAPD). The accuracy requirement is that the true mean VAPD should fall within ±.05 of the sample mean VAPD with 98% confidence.

Next the pooled estimate, S_p^2, of the common variance was determined from:

$$S_p^2 = \frac{\sum (n_i - 1)s_i^2}{\sum (n_i - 1)} \qquad (36)$$

where:

n_i = the number of observations in the trial sample, i

s_i^2 = the estimated variance from sample, i

From the results of the pilot study:

$$S_p^2 = .0191$$

From the estimated variance a pooled variance estimator (S^2) was determined from:

$$S^2 = \frac{S_p^2}{K} \qquad (37)$$

where:

$S_p^2 = .0191$

K = 6, the number of groups selected from the total population

Solving equation (37) :

$$\hat{S}^2 = .003$$

Finally, to determine the sample size required the following equation was used (Ref 28:189).

$$n = \frac{t_{\alpha/2}^2 \, s^2}{d^2} \qquad (38)$$

where:

$t_{\alpha/2}$ = tabulated t value for the desired confidence interval and the degrees of freedom of the initial sample.

d = the half width of the desired confidence interval

s^2 = the estimate of the variance obtained in the trial experiment.

Since the objective of the design study was to be at least 98% confident that the sample mean of VAPD falls within ±.05 of the true mean, the following parameters are used in finalizing the computation of sample size determination.

α = 2%

t = 2.82 with 9 d.f.

d = ±.05

therefore n = 9.5 $\sim$ 10.

Thus, the minimum number of replications required was ten. In order to determine the total number of computer runs, the following expression was used:

$$N = p(q_1^{k_1} * q_2^{k_2}) \qquad (39)$$

where:

k_1 = number of factors (input variables) at 3 levels

q_1 = number of levels for factor k_1 - 3

k_2 = number of factors at 5 levels

q_2 = number of levels for factor k_2 - 5

p = number of replications

N = total number of computer runs required

Solving for N:

$$N = (10)(3)^2(5)^1$$

$$N = 450 \text{ total runs required}$$

<u>Experimental Model</u>

The experimental design should quantify a solution to the problem statement of this thesis. Most experimental designs are based upon using either analysis of variance or regression analysis upon the data. In general, analysis of variance is used if any qualitative factors are present, and regression analysis is used if all the factors are quantitative (Ref 28:163). Since the factors are to be treated as levels of attainment, they may be thought of more in qualitative terms. For this reason an analysis of variance (ANOVA) approach was used. An underlying

assumption of ANOVA is that the variance within samples is homogenous (Ref 21:36). Cochrans test was used in checking for homogeniety of variance. The results of Cochrans test indicated the assumption of equal variances was reasonable. The remainder of this chapter describes the factors and factor levels used in the experiment.

The first factor, Force Mix, is set at five levels:

1. 0 ALCMs / 40 Bombers
2. 80 ALCMs / 32 Bombers
3. 200 ALCMs / 20 Bombers
4. 320 ALCMs / 8 Bombers
5. 400 ALCMs / 0 Bombers

Any number of force mix combinations could be chosen for this analysis, however, by testing the extremes and mid-point values, one can adequately measure the entire spectrum of force mixes upon which inferences can be drawn.

The second factor, Speed, is set at three levels, 380, 600, and 800 knots. The lowest level of speed, 380 knots is representative of present day bomber and ALCM speeds. The second level, 600 knots is used as the limiting speed for projected subsonic penetrators. The third level, 800 knots, was chosen as the limiting speed for projected supersonic penetrators. It has been stated that once aircraft are designed for speeds above Mach 1, life cycle and development costs skyrocket. Supersonic speed at low level does not add more effectiveness when comared to adding ECM and low RCS techniques (Ref 29:110). It was because of this assertion that the third speed level of 800 knots was investigated.

The third factor, RCS, is set at three levels. The lowest level is representative of a worst case RCS profile for each penetrator. Sub-

sequent RCS sets are successive 10 dB improvements over the worst case. See Table 2, page 30 for a complete description of the RCS values used in the model. The factors and levels are summarized in Table 4.

In summary, once the measure of effectiveness (VAPD), the appropriate sample size, and the experimental design were determined, the experiment was run. The next chapter presents and interprets the analysis of the results.

Table 4

Factors \ Levels	1	2	3	4	5
Force Mix	1	2	3	4	5
Bombers	100%	80%	50%	20%	0%
ALCM	0	20	50	80	100
Speed	380 knots	600 knots	800 knots	-	-
RCS	0 dB	-10 dB	-20 dB	-	-

The percentages for force mix denote the percentage of the total number of offensive weapons allocated to the particular weapon system. RCS values are in decibel level improvements from the reference case.

V. Data Analysis

In this chapter the analysis of the data will be presented in two sections. The first section will present the analysis for the response variable, VAPD (Value Average Probability of Damage) which is the measure of the proportion of the enemy target base destroyed. The second section will analyze the response variable, PSB (Probability of Survival of the Bomber). The control variables used are Force Mix (5 levels), Radar Cross Section (3 levels), and Speed (3 levels). Simulation runs were batched in five groups, one for each force mix. Each group contained 90 sample runs (3 levels of RCS x 3 levels of Speed x 10 replications). The data was written onto a data file which then was read into a statistical analysis package called SPSS (Statistical Package for the Social Sciences)(Ref 30). A total of 12 response variables were written onto the data file for model verification and validation which will be discussed in Chapter VI. The following section describes the effects of Force Mix, RCS, and Speed on VAPD.

VAPD

A three factor analysis of variance (ANOVA) was run using VAPD as the response variable. For a more complete description on how to interpret ANOVA results the reader is referred to Chapter 6 of "Fundamental Concepts in the Design of Experiments," by Charles R. Hicks. Appendix H contains the ANOVA tables for all SPSS runs. The data shows that all main and interaction effects were highly significant.

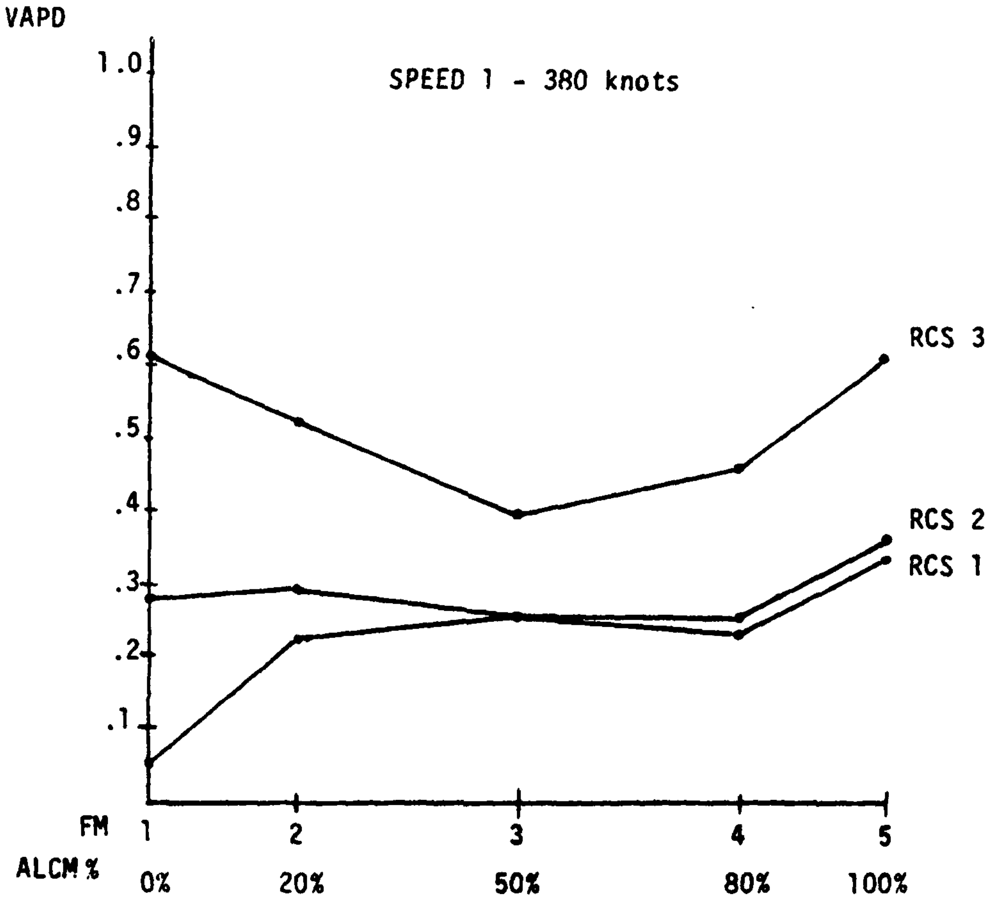
Main Effects. Speed and RCS were significant main effects as would be expected. Force Mix was also significant. Significance, as deter-

mined by ANOVA, only means that at least one level of the factor was statistically more significant than the others. ANOVA makes no inference as to which of the levels of a factor yielded statistically higher or lower values of the response variable. In order to determine those levels of the factors that had significant effects on the response variable a series of Newman-Keuls ranges tests were used to determine the significant differences between levels of Force Mix, Speed, and RCS. A statistical significance level of 5% was used. For a complete description of the Newman-Keuls ranges test the reader is referred to Reference 31:235. Each level of Speed and RCS was significantly different from the other with increasing Speed yielding higher values of VAPD as did higher levels (decreasing cross sections) of RCS. This is consistent with what one would expect to occur with improved Speed and RCS.

The factor, Force Mix, was analyzed at five levels with increasing levels indicating higher percentages of ALCMs in the total force. Force Mix level one is a 100% Bomber force while Force Mix level 5 is a 100% ALCM force. There was no statistical difference between Force Mix levels 1 through 4. Group five, however, was significantly higher, inferring that a pure ALCM force yields higher VAPD over all RCS and Speed groups. However, interaction effects were also highly significant, especially Force Mix and RCS. Interaction between two factors means that a change in response between levels of one factor is not the same for all levels of the other factor. The following subparagraph will discuss the impact of the interaction effects.

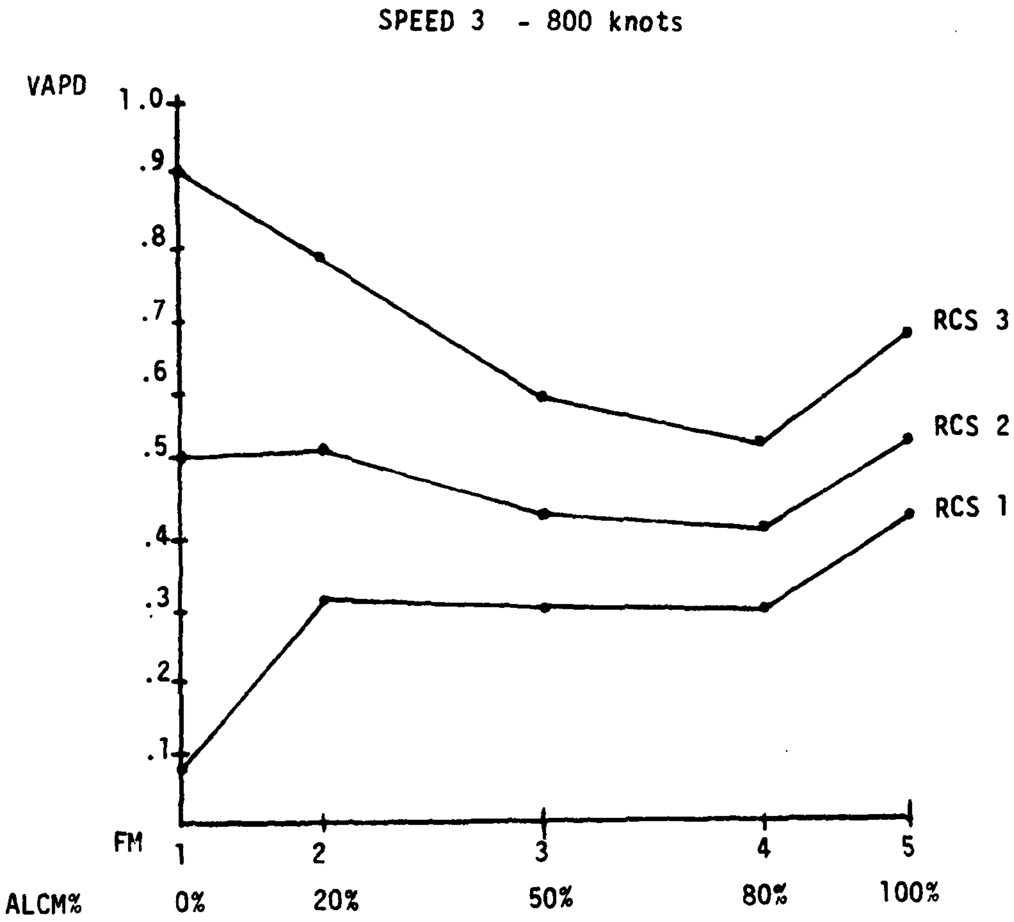
FM/RCS Interaction. The most significant interaction effect was the two-way interaction of Force Mix and RCS. Figure 10 is a plot of the response variable VAPD as a function of Force Mix (FM) at 380 knots for three different RCS groups. In interpreting this graph and all subsequent graphs in this chapter, it is important to note that the lines drawn between the data points only serve to emphasize the change in the response variable between levels. The fact that the lines are straight does not necessarily imply a linear relationship. For RCS groups 1 and 2, Force Mix level 5 dominates with a statistically higher value of VAPD than all other Force Mix levels. Dominance was statistically determined via additional Newman-Keuls ranges tests using sub-groups comprised of individual levels of RCS, Speed, and Force Mix. These tests will be explained in more detail in the section on three-way interaction on page 79. At RCS level 3, however, there is no statistical difference between the two highest VAPD values which occur at the extremes of a pure Bomber and pure ALCM force. Figure 11 shows the same plot for 800 knots. At 800 knots and RCS level 3 the pure Bomber force dominates. These effects are quite interesting and require some explanation.

At RCS level 1 the pure Bomber force does very poorly no matter what speed was used. Infusion of ALCMs dramatically improves the results. For all situations a characteristic rise in effectiveness occurs between Force Mix groups 4 and 5. It is at these force levels that the saturation and exhaustion factors of the ALCM begin to emerge. At 380 knots and RCS level 3, the overall capability of the force at first decreases with an increasing proportion of ALCMs. This implies that, on a one to one basis, the manned bomber with ECM is a more effective penetrator at



FM / RCS	1	2	3	4	5
1	.05	.22	.25	.23	.33
2	.27	.28	.24	.25	.36
3	.61	.52	.39	.46	.61

Figure 10 VAPD vs. FM - Speed 380 knots



FM / RCS	1	2	3	4	5
1	.08	.31	.30	.30	.43
2	.51	.52	.43	.41	.53
3	.90	.77	.59	.53	.67

Figure 11 VAPD vs. FM - 800 knots

this RCS level. However, once the proportion of ALCMs is increased to 80%, the saturation and exhaustion aspect of the ALCM force overcomes its lack of ECM. At 800 knots the RCS and Speed interaction is significant in that it pushes the pure Bomber force effectiveness to .9 which is statistically significantly higher than all other Force Mix combinations.

RCS/Speed Interaction. The interaction between RCS and Speed is also highly significant and warrants discussion. Figure 12 is a plot of the response variable VAPD as a function of RCS for the three different Speed levels. The values of VAPD used may be found in Table 5 on page 79. These values, shown in parentheses in Table 5, are the VAPD results of the dominant force mix group or subset of groups as determined by the Newman-Keuls ranges tests. In Figure 12 one notices that, for each RCS level, higher speeds yield higher VAPD. However the magnitude of this change increases with better RCS. At RCS level 1 the difference in VAPD between Speed 1 and Speed 3 is .10. However, at RCS level 3 the difference is .30. Thus speed and RCS are complementary, and together they mutually enhance the effects on VAPD.

FM/RCS/Speed Interaction. The three-way interaction between the factors was also highly significant. This implies that the force mix which dominates in terms of maximum VAPD is highly dependent upon the RCS and Speed level in question. In order to further investigate this interaction, nine one-way ANOVAs were run with VAPD by Force Mix for each RCS and Speed combination. A Newman-Keuls ranges test was performed on the means of the response variable VAPD to test for significant differences amongst the Force Mix groups. The significance level used was

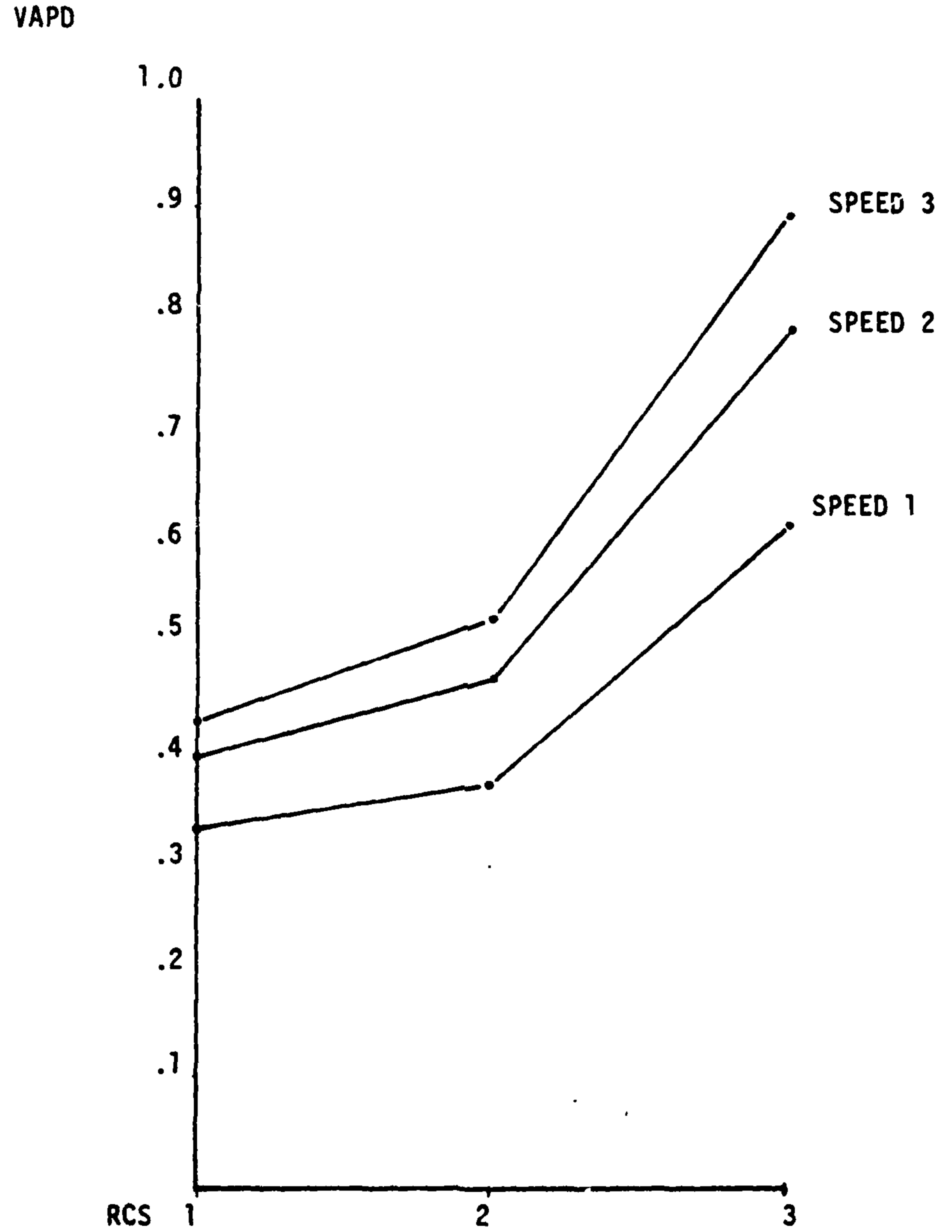


Figure 12 VAPD vs. RCS

5%. The following table shows the dominant Force Mix group for each combination of RCS and Speed. Two cases specify more than one force mix group. For these cases no single force mix group dominates and the groups specified within the cell comprise a homogenous subset which dominates the remaining groups. The numbers in parantheses are the means of the variable VAPD for the dominant group or subset.

RCS \ Speed	1	2	3
1	5 (.327)	5 (.397)	5 (.425)
2	5 (.363)	5 (.460)	1,2,5 (.520)
3	5,1 (.611)	1 (.789)	1 (.899)

Table 5 Dominant Force Mix Groups

PSB

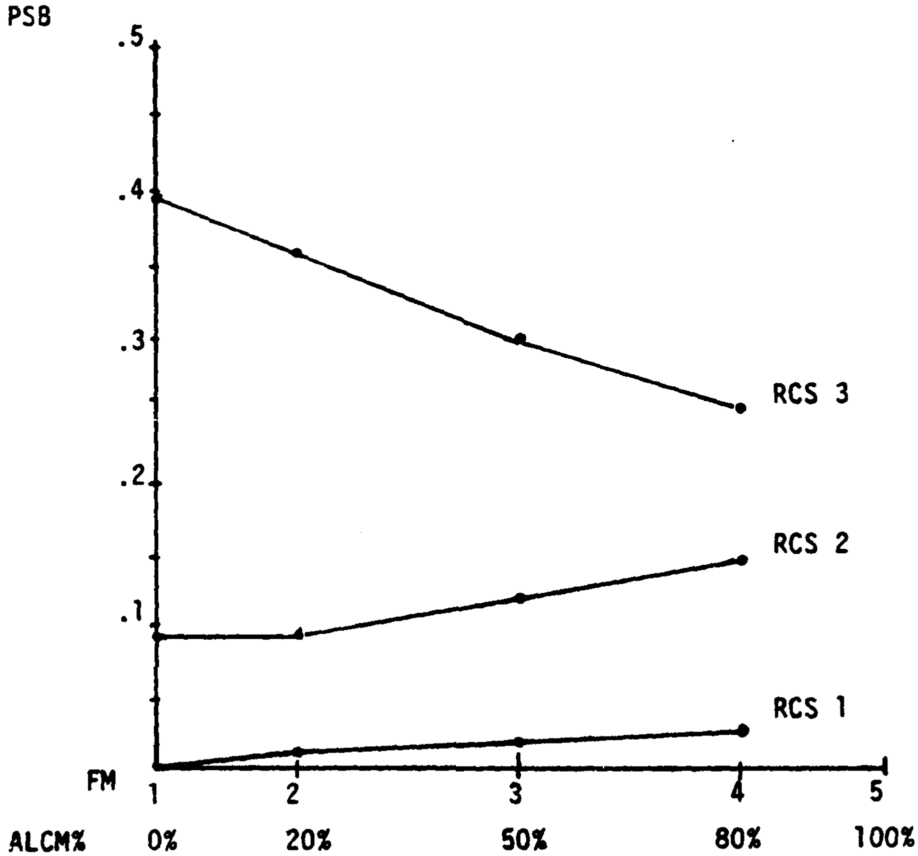
A three factor ANOVA using bomber survivability (PSB) as the response variable was run to determine the effect of the factors RCS, Speed, and Force Mix on bomber survivability. Appendix H shows the ANOVA results for this experiment.

Main Effects. Both RCS and Speed are highly significant while Force Mix is insignificant. Before conclusions can be drawn, an examination of the interaction factors is necessary.

RCS/Speed Interaction. Again RCS and Speed interaction was highly significant. RCS/Speed interaction was discussed in the previous section for the effects on the response variable VAPD. This same discussion may be extended for RCS/Speed interaction on the response variable PSB since survivability and value damage are such highly correlated issues.

FM/RCS Interaction. Figure 13 shows the results for PSB plotted against Force Mix for the three different RCS levels. The results are composites over all Speed groups. From this figure one notices an immediate inconsistency between the RCS levels. RCS levels 1 and 2 show an apparent upward trend in bomber survivability with increasing ALCM force mixes. However at RCS level 3 the opposite trend is evident. At first glance this appears inconsistent and counter intuitive. Further investigation is in order.

There were three levels of defenses modeled in DILUTE. These were the BSAM, the AI, and the TSAM. Three additional ANOVAs were run



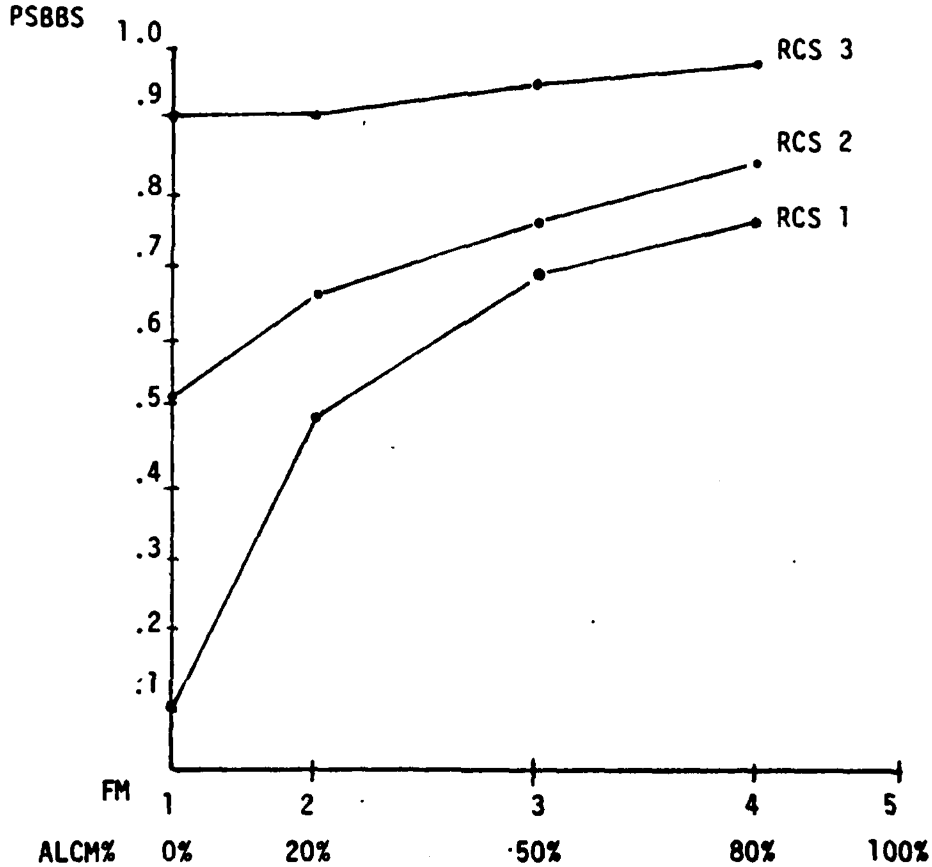
RCS \ FM	1	2	3	4	5
1	.00	.01	.02	.03	-
2	.08	.08	.12	.14	-
3	.37	.36	.30	.20	-

Figure 13 PSB vs. FM

with three factors each. The response variables used were Probability of Survival of the Bomber against the Band SAM (PSBBS), Probability of Survival of the Bomber against the Terminal SAM (PSBTS), and the Probability of Survival of the Bomber against the Airborne Interceptor (PSBAI). The ANOVA tables for these results are included in Appendix H. Figure 14 shows the plot of PSBBS with Force Mix. The data is a composite of all Speed levels. At the BSAM the bomber survivability increased dramatically with increasing ALCM force mixes. At RCS group 3 the results were less dramatic because the Bomber's low RCS combined with ECM make its survivability less dependent upon the saturation effects of the ALCM force.

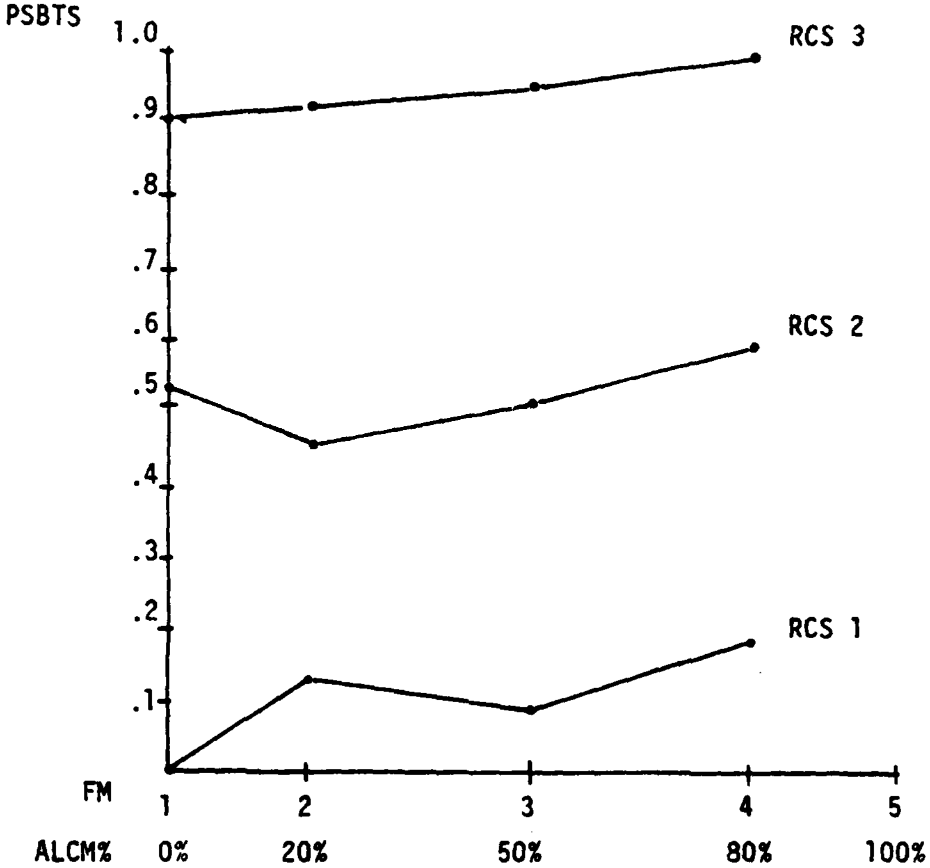
The impact on bomber survivability due to Force Mix at the TSAM is much less noticeable than at the BSAM as witnessed by the large difference in the F ratios for Force Mix between the BSAM and the TSAM (see Appendix H). In fact at the 1% level of significance the hypothesis that there is no significant difference between Force Mix levels for the TSAM cannot be rejected. This is as expected because of the thinning of the forces as they enter the final defense layer. Also TSAM saturation is very difficult to acheive because the offense cannot employ concentration of force in attempting to penetrate at this phase of the mission. Figure 15 shows the plot of PSBTS with Force Mix. There appears to be no inconsistencies of the type displayed in the PSB analysis.

The inconsistencies manifested themselves in the AI area. Figures 16, 17, and 18 show PSBAI and PSMAI (Probability of Survival of the ALCM against the AI) plotted against Force Mix levels for three different speeds. The ALCM survivability increases consistently with higher Force



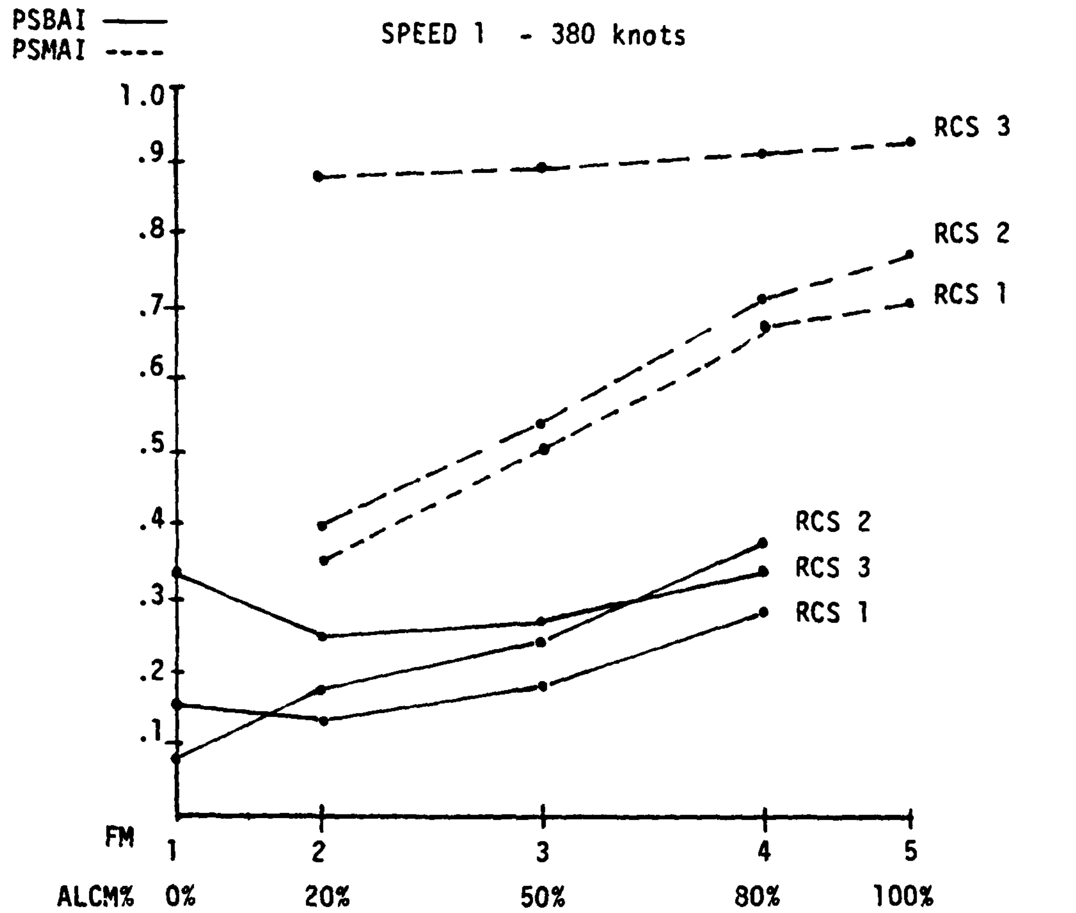
RCS \ FM	1	2	3	4	5
1	.09	.48	.68	.76	-
2	.51	.66	.76	.84	-
3	.90	.91	.95	.97	-

Figure 14 PSBBS vs. FM



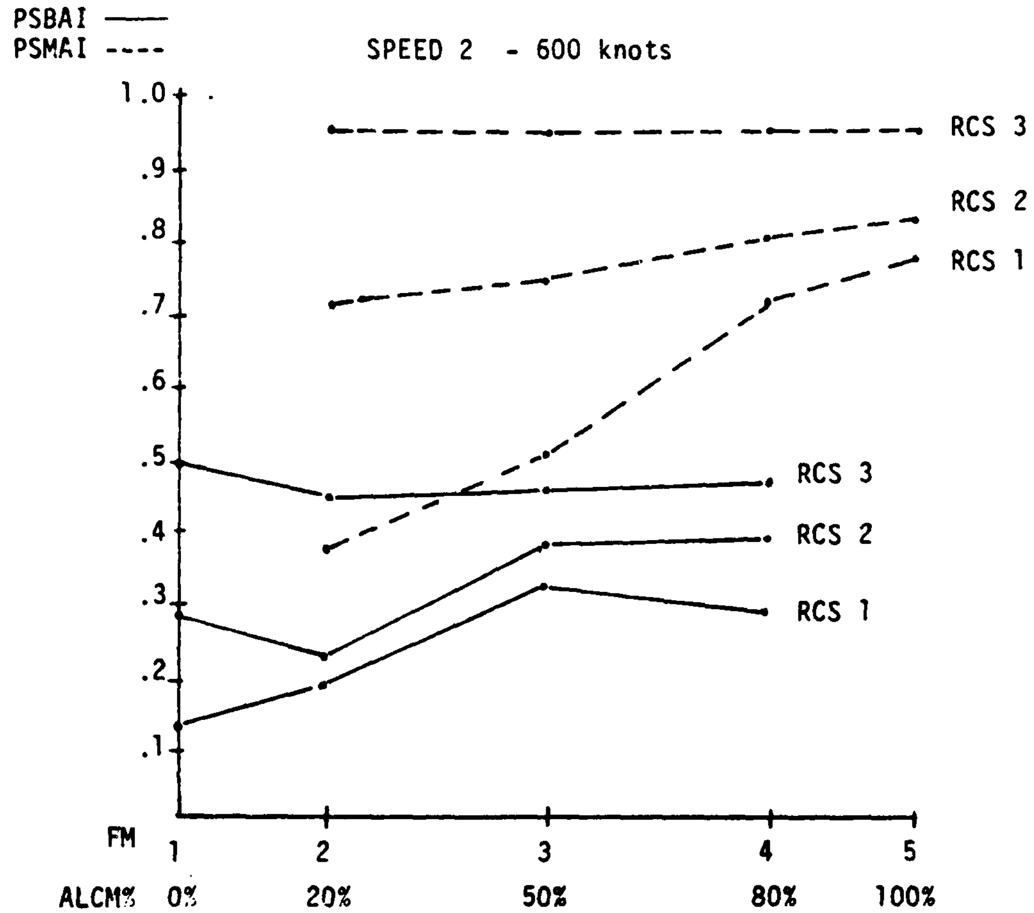
RCS \ FM	1	2	3	4	5
1	.00	.12	.08	.18	-
2	.52	.45	.51	.59	-
3	.90	.93	.95	.99	-

Figure 15 PSBTS vs. FM



RCS \ FM	1	2	3	4	5	
1	.07	.18	.25	.38	-	PSBAI
2	.16	.14	.19	.29	-	
3	.34	.26	.27	.35	-	
1	-	.36	.51	.68	.72	PSMAI
2	-	.41	.55	.73	.77	
3	-	.85	.90	.92	.93	

Figure 16 PSBAI & PSMAI vs. FM - 380 knots



RCS \ FM	1	2	3	4	5	
1	.13	.18	.32	.29	-	PSBAI
2	.28	.22	.37	.38	-	
3	.50	.45	.46	.47	-	
1	-	.37	.52	.72	.77	
2	-	.73	.75	.81	.81	PSMAI
3	-	.96	.95	.96	.96	

Figure 17 PSBAI & PSMAI vs. FM - 600 knots

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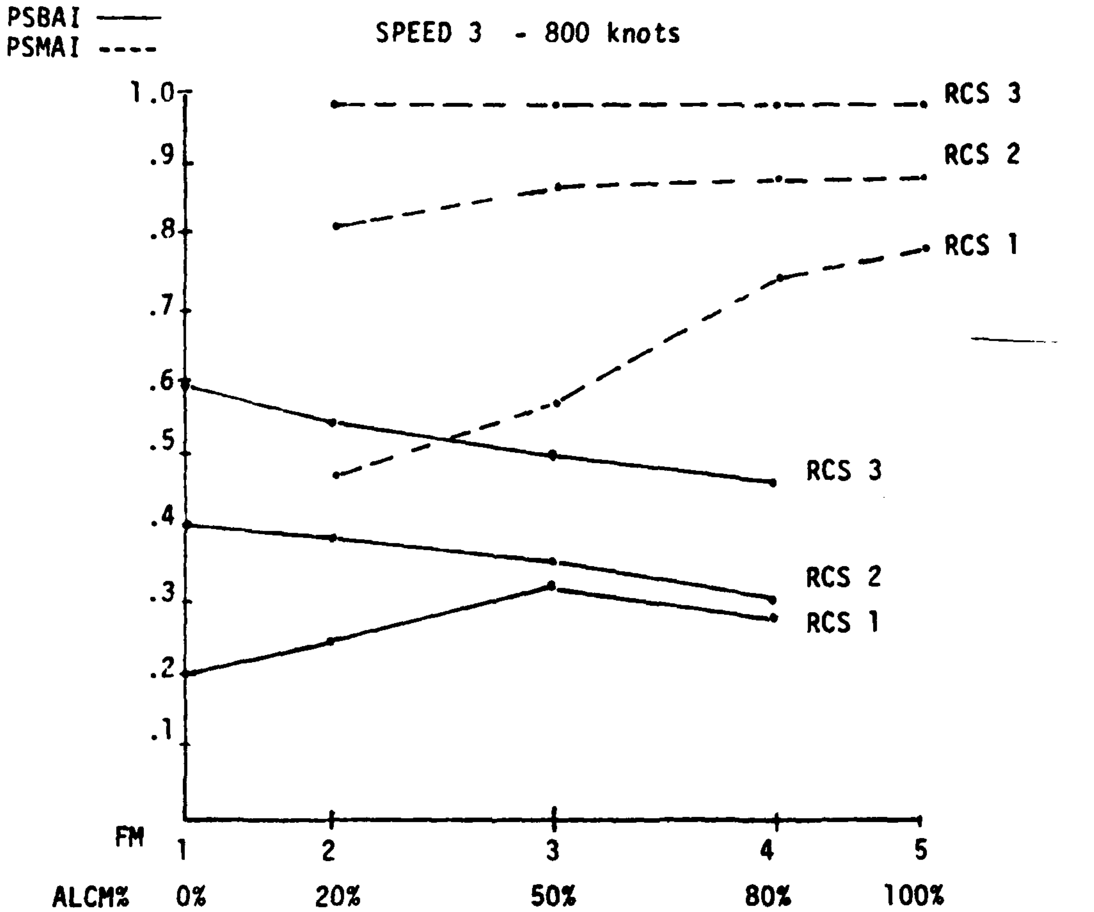

RCS \ FM	1	2	3	4	5	
1	.20	.25	.33	.27	-	PSBAI
2	.40	.39	.36	.31	-	
3	.59	.55	.51	.47	-	
1	-	.47	.57	.76	.79	PSMAI
2	-	.83	.87	.87	.88	
3	-	.99	.98	.98	.98	

Figure 18 PSBAI & PSMAI vs. FM - 800 knots

Mix levels. RCS level 3 improves ALCM survivability against the AI to values approaching 100% regardless of the force mix.

No such consistency is evident for the Bombers. The interaction here is a much more complex phenomenon. In fact it even appears that in some cases a Bomber RCS improvement to level 3 actually decreases Bomber survivability agains the AI. In order to explain this phenomenon it will be useful to restate some of the basic structure of the model DILUTE and to re-emphasize a certain feature of the experimental design.

In DILUTE, detection by ground sites is independent of RCS due to the excess radar transmitter power of these sites. However in the AI encounter, a figher's Probability of Detection and Conversion (PDC) is heavily dependent on RCS because it is technologically infeasible for a fighter to carry a radar with as large a power output as the ground site. When an ALCM's RCS is enhanced to level 3, the AI"s capability to find the ALCM is severely degraded to an average PDC of approximately 5%. This causes the fighter not to spend time either engaging the ALCM or using up his missile resources and having to land and rearm. This makes the fighters more readily available to engage the bomber. In the design of this experiment, Bomber RCS was not varied indepndently of ALCM RCS. Thus, when the bombers experienced a 20 dB improvement in RCS so did the ALCM.

To summarize, the effects of bomber survivability with increasing proportions of ALCMs in the force is significant at the BSAM with defense dilution by the ALCM enhancing the bomber's chances of survival. It is questionable whether the same can be said of the TSAM. While the trend shows an improvement in bomber survivability at the TSAM with

increasing ALCM force proportions, the results are much less significant than the BSAM results. Increasing proportions of ALCMs in the force had a marked detrimental effect to bomber survivability in the AI encounter at RCS level 3 because the fighters could not engage the ALCM leaving more fighter resources available to engage decreasing numbers of bomber penetrators.

This chapter has explained the analysis of the data obtained in the experiment. The next chapter explains the verification/validation of the model.

VI. Verification/Validation

In order to establish credibility in the results of any simulation modeling effort a "validation" process must be undertaken. There is no clear line distinguishing between what is called verification and what is referred to as validation. Fishman and Kiviat (Ref 33:30) divide ~~the~~ evaluation of simulations into three categories:

> (1) verification - insures that the model behaves as the modeler intended it to behave.
>
> (2) validation - tests the agreement between the behavior of the model and that of the real system.
>
> (3) problem analysis - draws statistically significant inferences from the data generated by the model.

Problem analysis was discussed in detail in the previous chapter. The remainder of this chapter is devoted to establishing credibility in the results obtained from the model DILUTE. The chapter is divided into two parts. Part one deals with verification and part two contains a discussion of validation.

Verification

The process used in model verification may be divided into three parts. These parts are: Network Construction, FORTRAN Subprograms, and the TRACE Option.

Network Construction. The flows of the penetrators were modeled on a network pattern with the three tiers of defenses (BSAM, AI, and TSAM) and verified one tier at a time. As each layer was added the

flows into and out of each section were checked for consistency. In order to accomplish this, a tally was kept of the number of entities which completed certain key activities. The tallies are tracked within SLAM by the array NNCNT(I) which represents the number of times activity number I was accomplished. For example, in tracking the transactions through corridor number one of the Band SAM the following network relationships are noted:

# of Pens entering corridor 1 BSAM	=	# of Pens not detected and thereby bypassing BSAM	+	# of Pens escaping BSAM due to SAM saturation	+	# of Pens killed by BSAM engagement	+	# of Pens surviving BSAM engagement

These relationships are expressed mathematically by:

NNCNT(I) = NNCNT(78) + NNCNT(9) + NNCNT(7) + NNCNT(8)

See Appendix A for the arcs which these activity numbers represent. If this equation had not balanced, it would have pointed out problems in the network flow.

<u>FORTRAN Subprograms</u>. The user functions were computerized and verified separately. The verification was accomplished with TI-59 hand calculations. The most complex functions modeled were the calculation of the Probability of Damage on a target and the mini-simulation of the SAM encounter. Program PSI was used to calculate target PD. The inputs for this program are weapon yield, height of burst, miss distance, and target vulnerability. An example of the output with intermediate calculations is included in Appendix I.

Program SAX was developed as a one-on-one simulaiton of the SAM

encounter. Inputs are penetrator type, speed, RCS group, missiles remaining on the launcher, distance offset from the site, range of initial detection, and time of entering and time of exiting coverage. A sample output of SAX is also included in Appendix I.

TRACE Option. The TRACE function of SLAM is an option that is invoked in order to track events and individual entities with their attributes through the network. This option was used throughout the building phase of the computerized model. Data from a TRACE report has been extracted and is included in Appendix I.

Validation

While verification is the process of building confidence in the results obtained from the model, validation is the process of building confidence that the model behaves as would the real system (Ref 33:v). Actual statistical comparisons between model output and the real world would be an ideal validation. Such a validation is certaintly impossible for the model DILUTE because the real world that DILUTE models, strategic penetration of enemy territory in a nuclear war, has yet to occur. Other methods must be found to build confidence in the model output.

Schlesinger (Ref 34:927-933) suggests validating models by establishing the reasonableness, or face validity of the model. He divides this into tests for continuity, consistency, degeneracy, and internal validity. These tests are discussed in the remainder of this chapter.

Continuity. Continuity is tested by insuring that changes in the output data are commensurate with changes in the input data. This process is thoroughly documented in Chapter V, Data Analysis. The results of

Chapter V show that penetrator survivability and damage levels responded as expected with higher penetrator speeds yielding higher values of survivability and damage levels as did improved Radar Cross Sections.

Consistency. Consistency is tested by insuring that the model yields similar results when similar cases are run. DILUTE's runs were tested for consistency with various random number streams which yielded statistically similar results for the same input data.

Degeneracy. Degeneracy is demonstrated when parameter values are chosen in order to eliminate a feature of the model and then the model reacts as if the feature is not there. For example, in DILUTE,saturation and exhaustion of the defenses was a major feature that was modeled. It was hypothesized that saturation was to play a major role in force effectiveness when a high proportion of ALCMs was used and not so large a role when a high proportion of bombers was used. Two samples of 10 runs each were accomplished with saturation eliminated. Saturation was eliminated by allowing the SAM launchers to be loaded with 100 missiles each (instead of 4) at the start of the simulation. The values of the control variables for each sample were:

	Force Mix	RCS	Speed
sample #1	2	3	3
sample #2	5	3	3

Two response variables were chosen. The first variable was VAPD, which was the primary Measure of Effectiveness of the model. The second response variable is Probability of Escaping the Band SAM (PESCBS) which

is the proportion of the total number of penetrators escaping the Band SAM threat due to saturation. The mean values of the response variables are shown below:

	VAPD		PESCBS	
	4 msls/ launcher	100 msls/ launcher	4 msls/ launcher	100 msls/ launcher
Force Mix - 20% ALCM	.79	.77	.211	.208
" 100% ALCM	.67	.02	.645	.003

As can be seen from the values, changing the number of missiles per launcher had an insignificant effect on force effectiveness and saturation when the force consisted of only 20% ALCM. However when the force was comprised of all ALCM the results changed dramatically.

Internal Validity. Internal validity is established if the model responds as expected when runs are made with certain factors set well beyond the limits of the study. DILUTE was sampled at 200 knots and at 2000 knots. The conditions of the sample runs were:

	FM	RCS	Speed	Replications
#1	2	3	200	10
#2	2	3	2000	10

The results of these runs along with the results of the design study using the established values of Speed are shown below:

	200K	380K	600K	800K	2000K
VAPD	.40	.52	.67	.77	.94

The results show that the response variable VAPD demonstrates consistency at the extremes.

Another check that was made was to change one of the assumptions of the model and see that the variable VAPD behaved as expected. DILUTE is modeled with a weapon to target ratio of 2:1. A check of the response of the variable VAPD was made with a weapon to target ratio of 1:1. Ten runs were accomplished with the control variables set at:

FM = 4 (80% ALCM)

RCS = 3

Speed = 600 knots

The mean value of VAPD was .11 as compared with a VAPD of .52 with a 2:1 weapon to target ratio. Due to the saturation aspects of this force mix, the effectiveness more than doubled when the weapon to target ratio was doubled. Therefore this establishes the internal validity of the model.

In summary, model verification was accomplished by verifying each phase of the model as it was constructed. The design of the model lent itself to this by the structuring of tiers of defenses and by modular FORTRAN subroutines. Internal verification was built in by tracking activity counts throughout the stages of the network. The TRACE report was used extensively in tracking individual penetrators through the network. Model validation was accomplished by building confidence in the face validity of the results. Basically this was accomplished by a sensitivity analysis on the control variables and by checking the response of the model when certain assumptions were varied.

VII. Conclusions & Recommendations

This thesis was devoted to developing a mini-campaign model for studying the effectiveness of various ALCM/manned penetrator force mix combinations. This chapter is divided into two parts. Part one contains the conclusions reached through this study effort. Part two contains recommendations based on the analysis of the results obtained from the model DILUTE.

Conclusions

The conclusions of this thesis effort are:

1. Given the structure of this experiment, significant differences do exist between force mix combinations of ALCM and manned bombers, however the results are highly dependent upon the factors of RCS and Speed.

2. Bomber survivability against the peripheral defense of the BSAM can be significantly enhanced if the bombers are used in concert with cruise missiles due to the defense dilution aspect of the ALCM. The same effect is true against the AI as long as the AI has a reasonable chance of detecting the ALCM. When the AI could not detect the cruise missile, bomber survivability decreased because more fighter resources were available to engage the bomber. Enhancement of bomber survivability by ALCM dilution at the TSAM is not statistically significant at the 1% level.

3. Pure forces dominate mixed forces as can be seen in Table 5. The dominant characteristics of the forces are ECM for the bomber and saturation for the ALCM. The results of the study imply that for a force to be effective, one of these aspects must be exploited.

4. The decisions on force mix are heavily dependent upon RCS and Speed improvements. At the low end of the spectrum of these factors the pure ALCM force dominates. RCS and Speed improvements significantly enhance the bomber's ECM capability causing a pure bomber force to dominate at the higher levels of RCS and Speed.

The results of the experiment also led to some conclusions which did not directly relate to the objectives of the thesis effort. These conclusions are:

1. Speed and RCS are complementary and together they mutually enhance value damage.

2. It is evident from Figure 12 that the change in mission effectiveness is greater for a speed improvement from 380 knots to 600 knots than from 600 knots to 800 knots. This implies decreasing marginal benefits in effectiveness with higher speeds.

Recommendations

As was noted in the data analysis section, the manned bomber with an enhanced RCS and Speed profile was a much more effective weapon system than the ALCM. This was evident because as the ALCM force percentage was increased there was a substantial drop in effectiveness until the ALCM force size was increased to the point of defense saturation at which point ALCM effectiveness began to rise. At improved RCS and Speed levels the ALCM, even with significantly lower radar cross sections than the bomber, could not compete on a one for one basis with the manned penetrator. The difference: ECM. For this reason the authors conclude

that immediate research be undertaken to implement an ECM equipped ALCM. Assuming that this is feasible, ECM should be given priority over further RCS reductions on the ALCM.

VIII. Recommendations for Follow-On Study

This research effort could not address all aspects of the system studied or answer all the questions that need to be asked. Some recommended areas for follow-on study concerning strategic force mix options are discussed in the following paragraphs.

As mentioned in the previous chapter, an ECM equipped ALCM was recommended as a future generation unmanned penetrator. Research needs to be done to determine the tradeoffs between ECM power added, range degradation, and targets destroyed.

Saturation played a major role in ALCM effectiveness. The use of decoys should be investigated to determine if saturation levels could be acheived in a cheaper manner.

Since saturation does play such a major role in ALCM force effectiveness, a sensitivity analysis could be done on the defense concetration levels. While the defense levels were carefully researched and are representative of high threat target areas, a study could be done to determine the sensitivity of the results to changes in defense strength.

The ALCMs and Bombers were traded off on a warhead for warhead basis. Assuming the bomber's weapon load was ten offensive weapons, the tradeoff of ALCMs to bombers was 10:1. A study could be done analyzing the tradeoffs between equal cost forces. In costing the ALCMs the cost of the ALCM carriers needs to be included.

Overpressure and target damage response was carefully modeled with extensive detail. This allows for studies to be accomplished using a wide range of target types. In this study the penetrators attacked

relatively soft urban/industrial targets. Research could be done using hardened targets or a mix of target types.

DILUTE was a force on force model of offense vs. defense. However, the ECM engagements were modeled on a one on one basis. This is offense conservative in that bombers flying in the vicinity of cruise missiles could provide "buddy" standoff ECM support. This is also a limitation that has been identified in the APM (Advanced Penetrator Model) by Hoeber (Ref 10:104).

ECM effectiveness against the SAM was explicitly modeled by establishing weapon CEP as a function of range and J/S noise ratio. However ECM effectiveness against the AI was implicitly modeled using an ECM factor derived from an existing model (this same approach is also used in APM). The same methodology used in the SAM encounter could be incorporated into the AI engagement by calculating weapon CEP as the fighter closed on the penetrator.

One advantage of the manned bomber that was not modeled was the ability of the bomber to perform damage assessment (DAS) to determine whether to strike a target or to withold the weapon for use on an unstruck target. Presently in DILUTE if a bomber's target has been destroyed, the bomber still delivers a weapon on the target. This adds no value to the total value destroyed computation. Meanwhile there are other targets that go unstruck. While it is reasonable to assume no DAS for SRAM missiles fired in the forward azimuths, the bomber gravity weapons could be used with DAS employment methods.

A more extensive statistical analysis could be accomplished using response surface methodology (RSM). Shannon (Ref 28:169-171) states

that if the dependent (VAPD) and independent (FM,Speed, RCS) variables are quantitative and continuous, RSM is usually the most appropriate approach to use in determining optimality in simulation projects. RSM involves a series of small experiments with a full or fractional factorial design in order to explore the response surface. Once the peak of the surface (optimum) condition is found one needs to determine the equation of the response surface as a function of the independent variables in the area near this optimum. More underlying philosophy and use of RSM techniques can be found in a number of other textbooks including "The Design and Analysis of Industrial Experiments", by Davies, "Experimental Design", by Cochran and Cox, and "Fundamental Concepts in the Design of Experiments", by Hicks.

The areas mentioned in this chapter are the major aspects of DILUTE that could be expanded and studied. It is impossible to say whether or not incorporation of any or all of these features would significantly affect the output of the model. DILUTE, in its present form, does accomplish the purpose for which it was designed to the necessary degree of accuracy.

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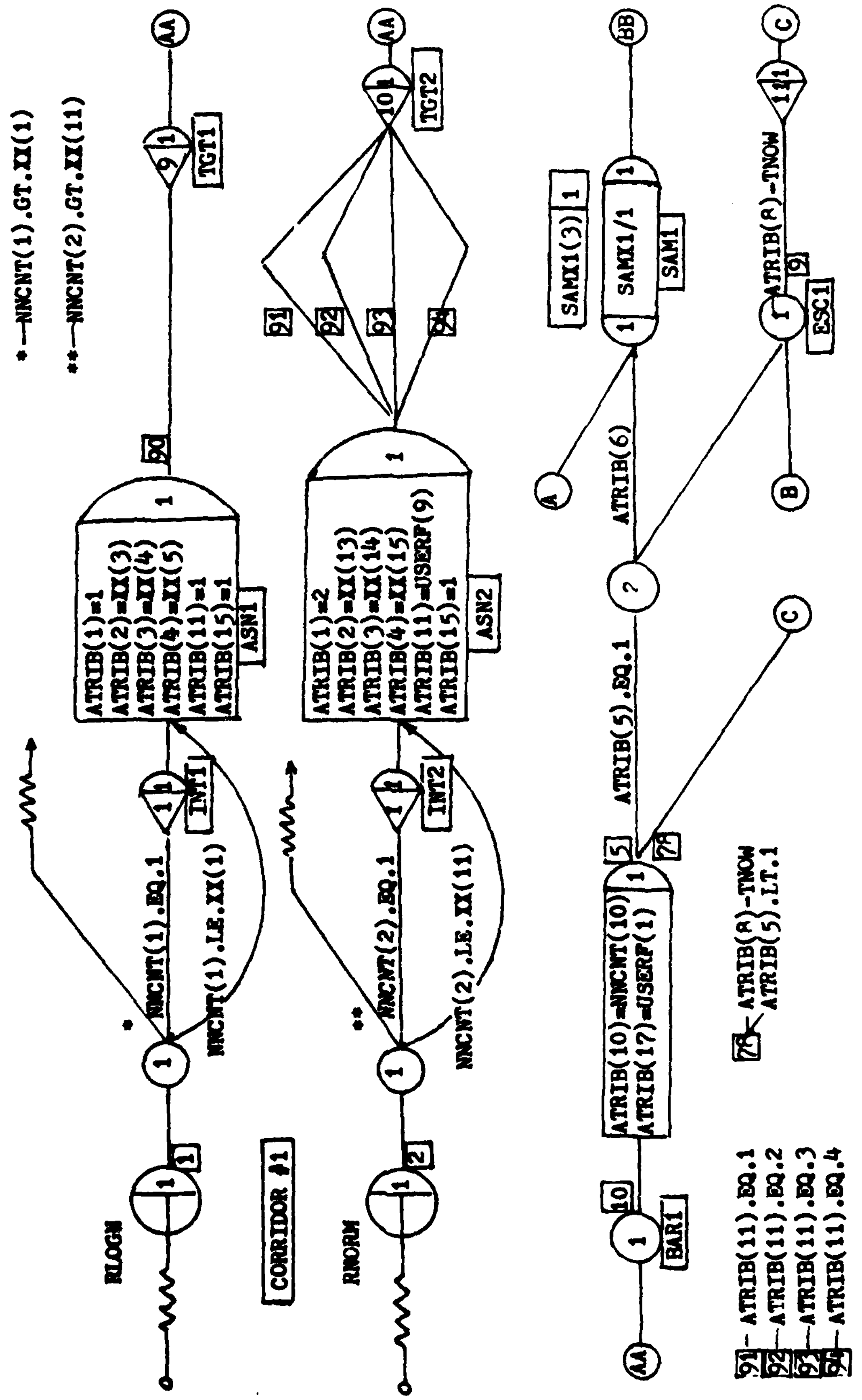
35. TI58C/59 Master Library Users Manual, Texas Instruments,Inc.,1979.

* Although the overall classification of these documents is SECRET, the portions referenced were extracted from unclassified sections.

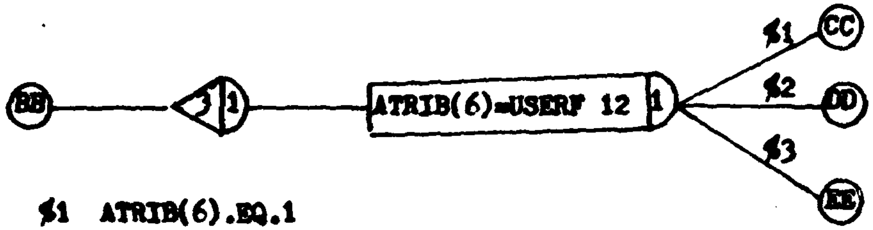
APPENDICES

APPENDIX A

SLAM STRUCTURAL MODEL

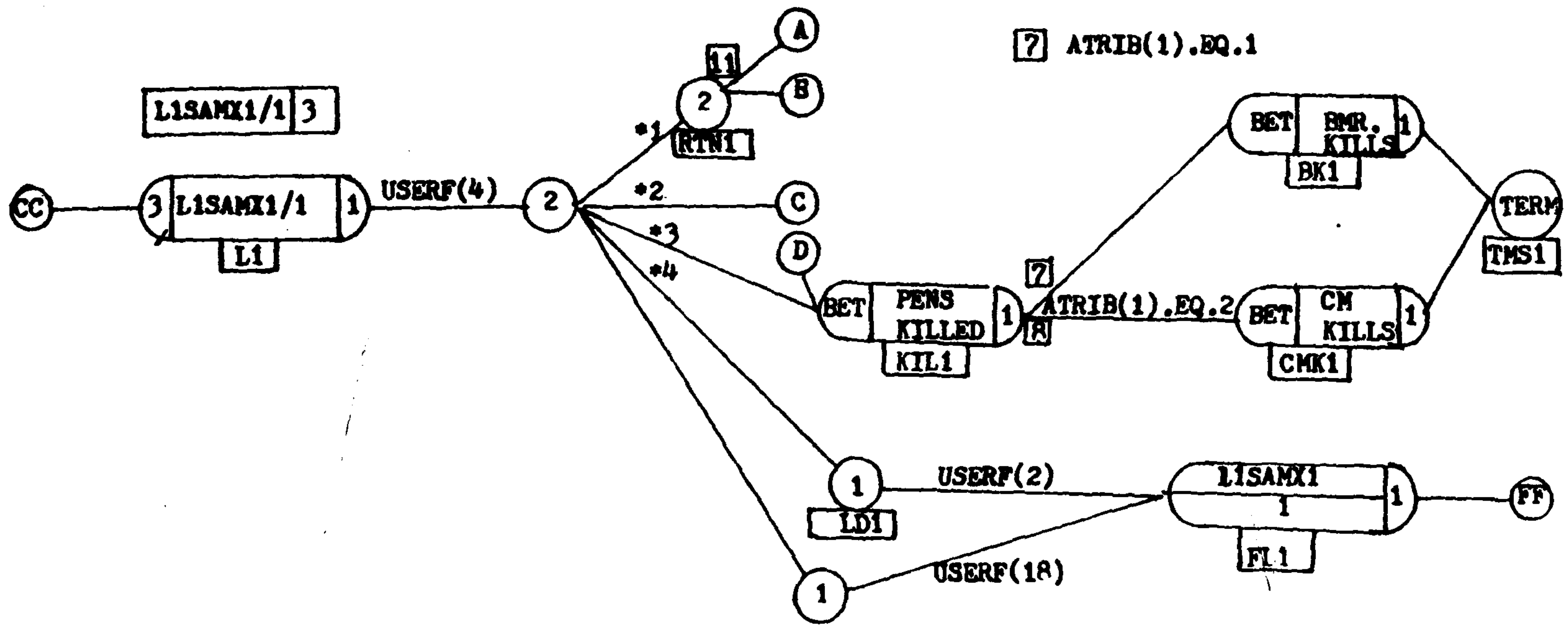


*—NNCNT(1).GT.XX(1)
**—NNCNT(2).GT.XX(11)
RLOGN
1
1
1
*
NNCNT(1).EQ.1
NNCNT(1).LE.XX(1)
1 1
INT1
ATRIB(1)=1
ATRIB(2)=XX(3)
ATRIB(3)=XX(4)
ATRIB(4)=XX(5)
ATRIB(11)=1
ATRIB(15)=1
ASN1
1
90
9 1
TGT1
AA
CORRIDOR #1
RNORM
1
2
1
**
NNCNT(2).EQ.1
NNCNT(2).LE.XX(11)
1 1
INT2
ATRIB(1)=2
ATRIB(2)=XX(13)
ATRIB(3)=XX(14)
ATRIB(4)=XX(15)
ATRIB(11)=USERF(9)
ATRIB(15)=1
ASN2
1
91
92
93
94
10 1
TGT2
AA
AA
10
1
BAR1
ATRIB(10)=NNCNT(10)
ATRIB(17)=USERF(1)
1
5
78
ATRIB(5).EQ.1
?
ATRIB(6)
A
1
SAMX1/1
1
SAM1
SAMX1(3)
1
BB
C
B
I
ESC1
9
ATRIB(8)-TNOW
1 1
C
78— ATRIB(8)-TNOW
ATRIB(5).LT.1
91— ATRIB(11).EQ.1
92— ATRIB(11).EQ.2
93— ATRIB(11).EQ.3
94— ATRIB(11).EQ.4

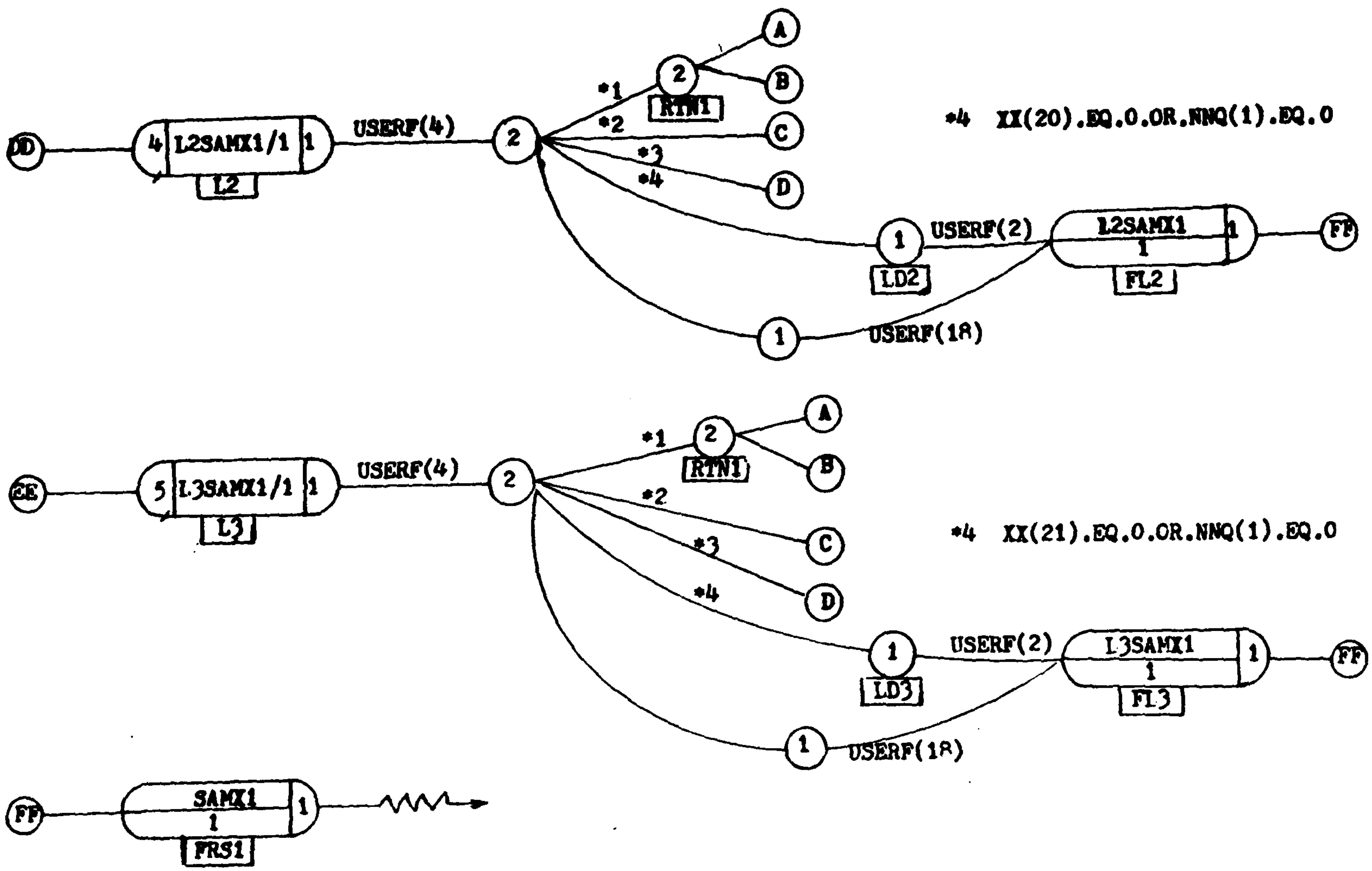


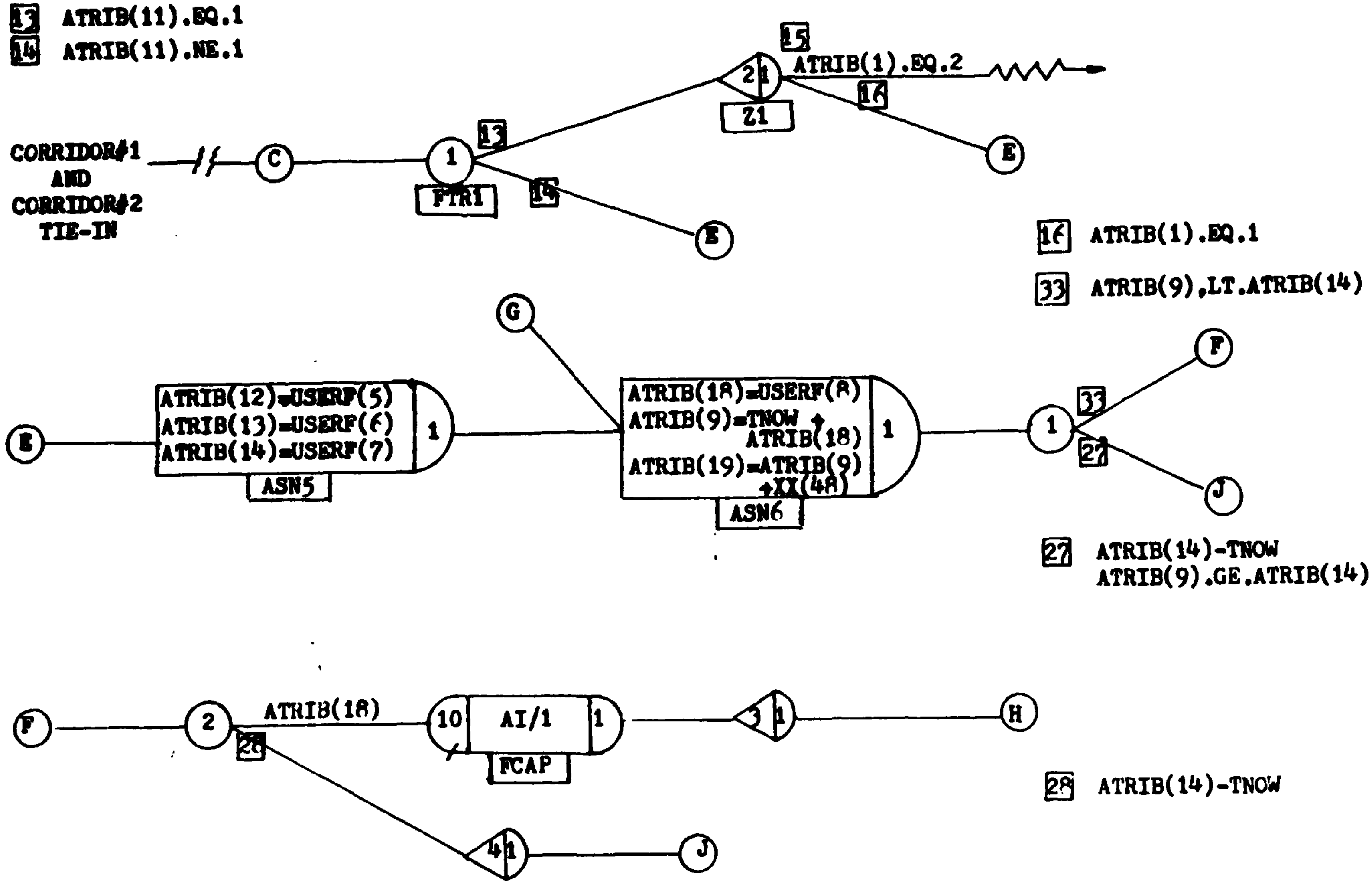
$1 ATRIB(6).EQ.1
$2 ATRIB(6).EQ.2
$3 ATRIB(6).EQ.3

*1 ATRIB(5).EQ.0.AND.TNOW.LT.ATRIB(8)
*2 ATRIB(5).EQ.0.AND.TNOW.GE.ATRIB(8)
*3 ATRIB(5).EQ.1
*4 XX(19).EQ.0.OR.NNQ(1).EQ.0

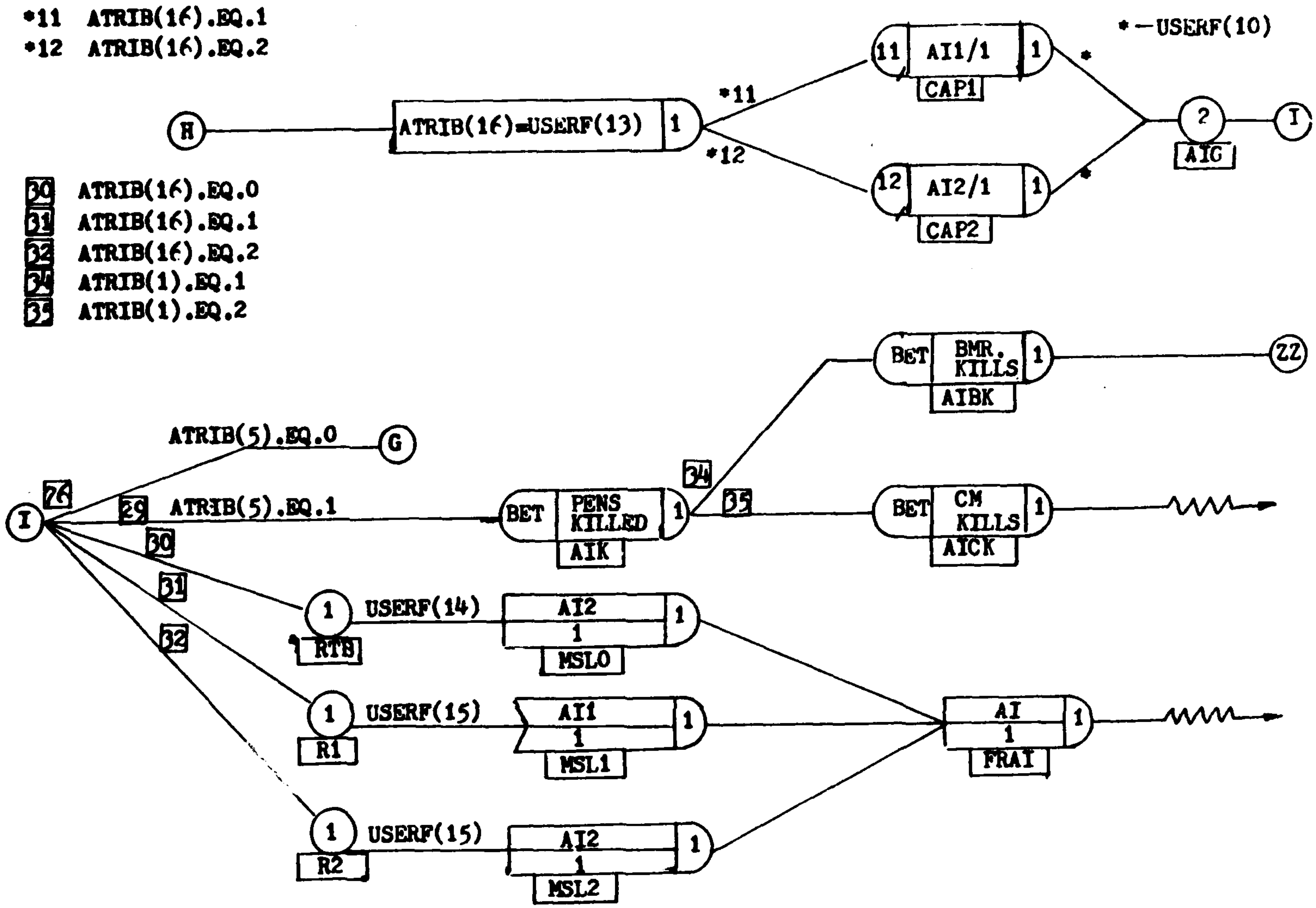


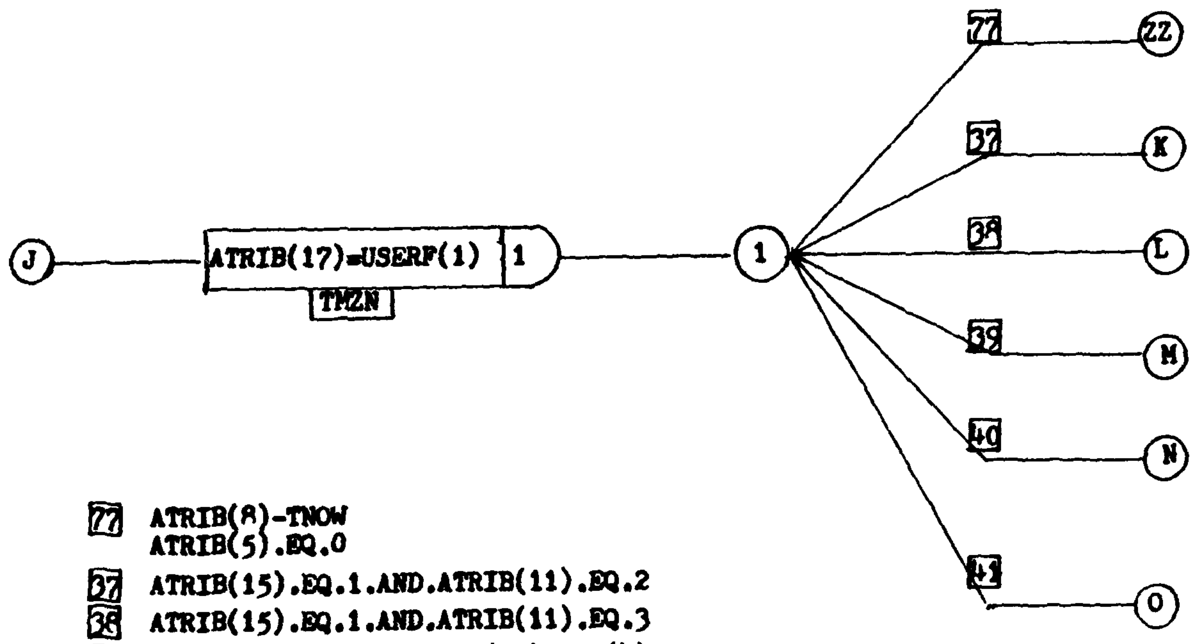
[7] ATRIB(1).EQ.1


L2SAMX1/1
L2
USERF(4)
RTN1
*1
*2
*3
*4
*4 XX(20).EQ.0.OR.NNQ(1).EQ.0
USERF(2)
L2SAMX1
LD2
FL2
USERF(1R)
L3SAMX1/1
L3
RTN1
*4 XX(21).EQ.0.OR.NNQ(1).EQ.0
L3SAMX1
LD3
FL3
SAMX1
FRS1



13 ATRIB(11).EQ.1
14 ATRIB(11).NE.1
CORRIDOR#1 AND CORRIDOR#2 TIE-IN
C
1
FTR1
13
14
E
2 1
15
Z1
ATRIB(1).EQ.2
16
E
16 ATRIB(1).EQ.1
33 ATRIB(9),LT.ATRIB(14)
E
ATRIB(12)=USERF(5)
ATRIB(13)=USERF(6)
ATRIB(14)=USERF(7)
1
ASN5
G
ATRIB(18)=USERF(8)
ATRIB(9)=TNOW + ATRIB(18)
ATRIB(19)=ATRIB(9) +XX(48)
1
ASN6
1
33
27
F
J
27 ATRIB(14)-TNOW
ATRIB(9).GE.ATRIB(14)
F
2
28
ATRIB(18)
10
AI/1
1
FCAP
3 1
H
4 1
J
28 ATRIB(14)-TNOW


*11 ATRIB(16).EQ.1
*12 ATRIB(16).EQ.2
30 ATRIB(16).EQ.0
31 ATRIB(16).EQ.1
32 ATRIB(16).EQ.2
34 ATRIB(1).EQ.1
35 ATRIB(1).EQ.2
* — USERF(10)
H
ATRIB(16)=USERF(13)
1
*11
*12
11
AI1/1
CAP1
12
AI2/1
CAP2
*
*
2
AIG
I
I
76
ATRIB(5).EQ.0
G
29
ATRIB(5).EQ.1
30
31
32
BET
PENS KILLED
AIK
34
35
BET
BMR. KILLS
AIBK
ZZ
BET
CM KILLS
AICK
1
USERF(14)
RTB
AI2
1
MSL0
1
USERF(15)
R1
AI1
1
MSL1
1
USERF(15)
R2
AI2
1
MSL2
AI
1
FRAT



77 ATRIB(8)-TNOW
ATRIB(5).EQ.0

37 ATRIB(15).EQ.1.AND.ATRIB(11).EQ.2

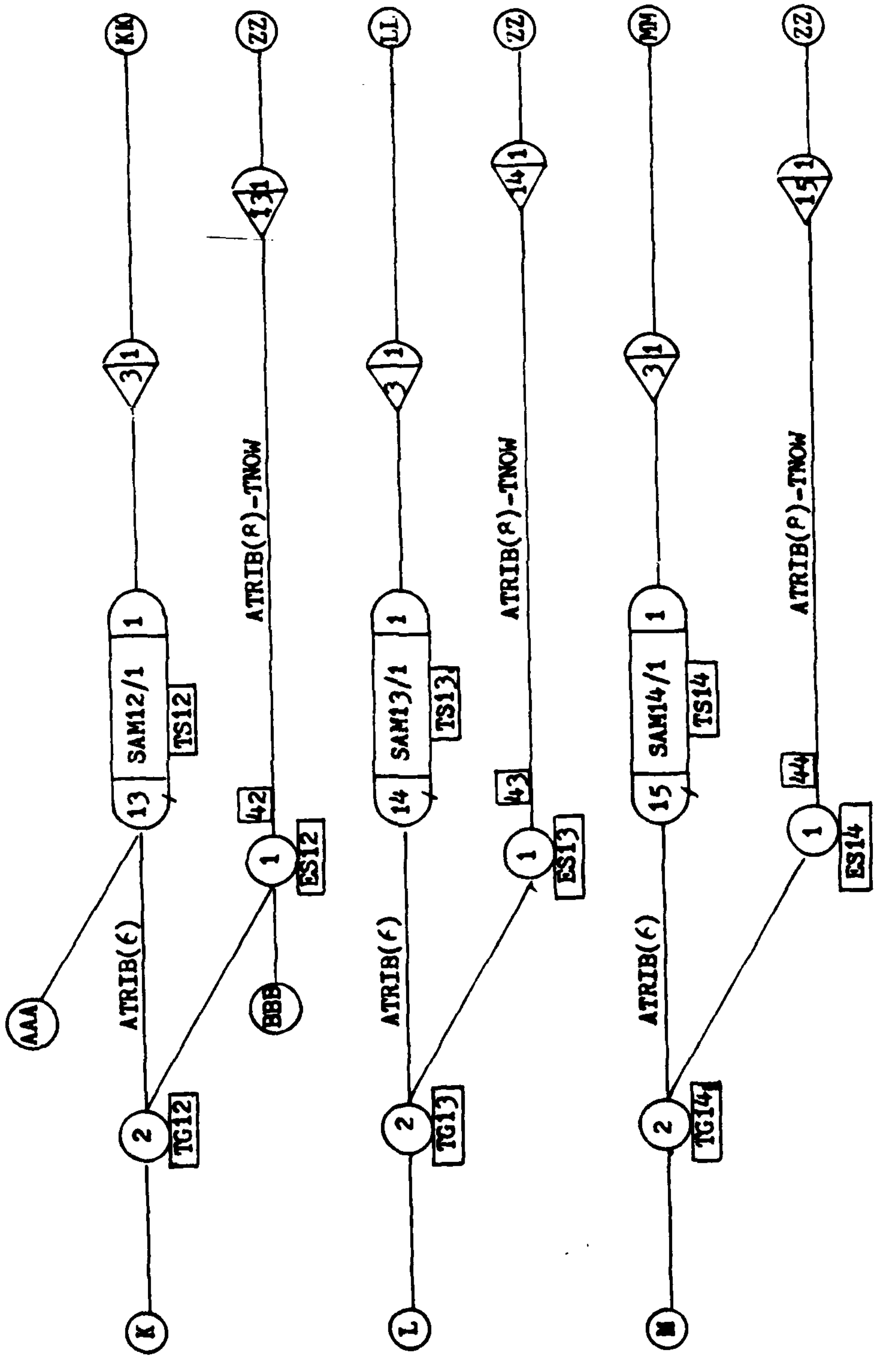
38 ATRIB(15).EQ.1.AND.ATRIB(11).EQ.3

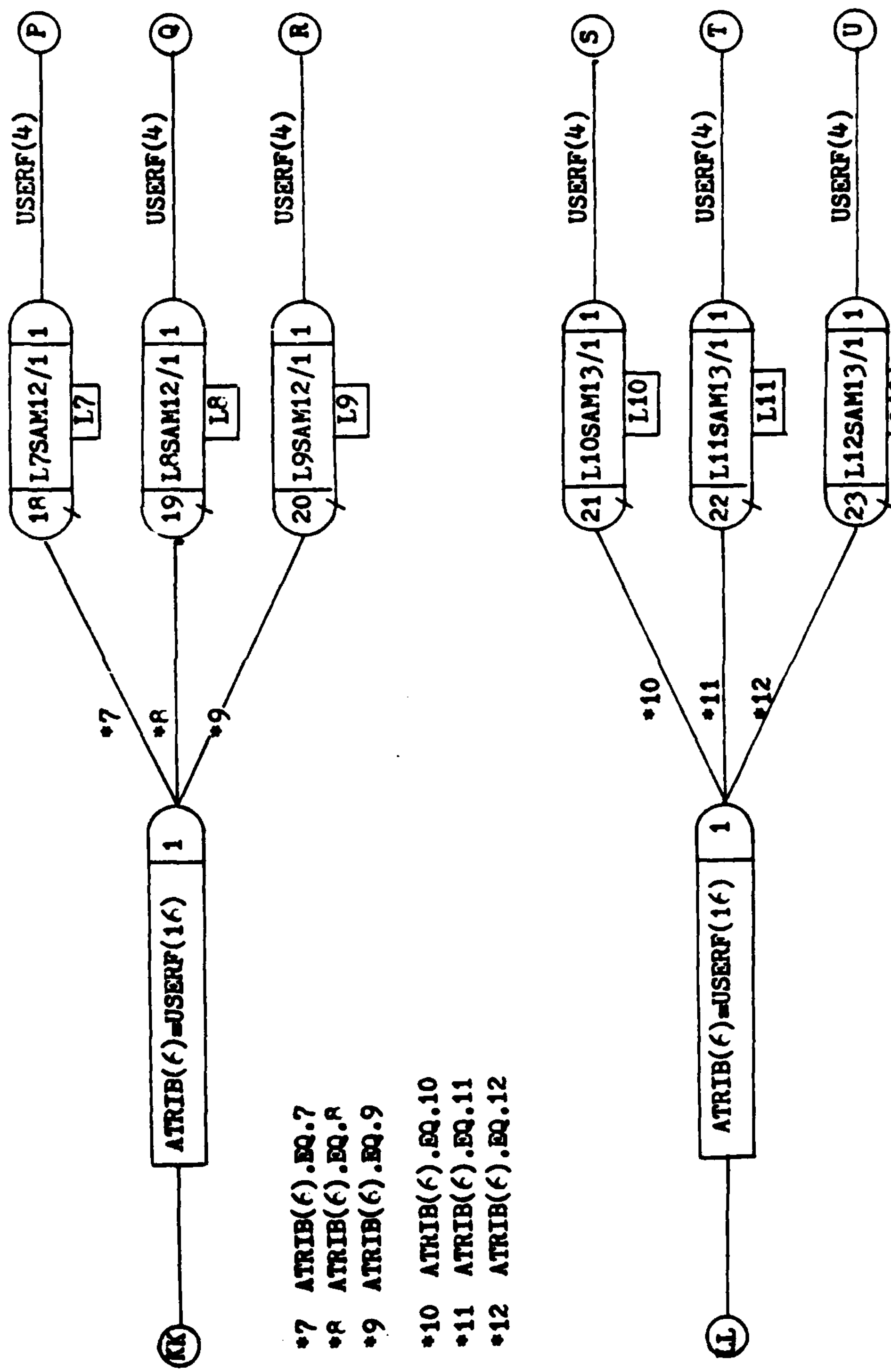
39 ATRIB(1).EQ.1.OR.ATRIB(11).EQ.(4)

40 ATRIB(15).EQ.2.AND.ATRIB(11).EQ.3

41 ATRIB(15).EQ.2.AND.ATRIB(11).EQ.2

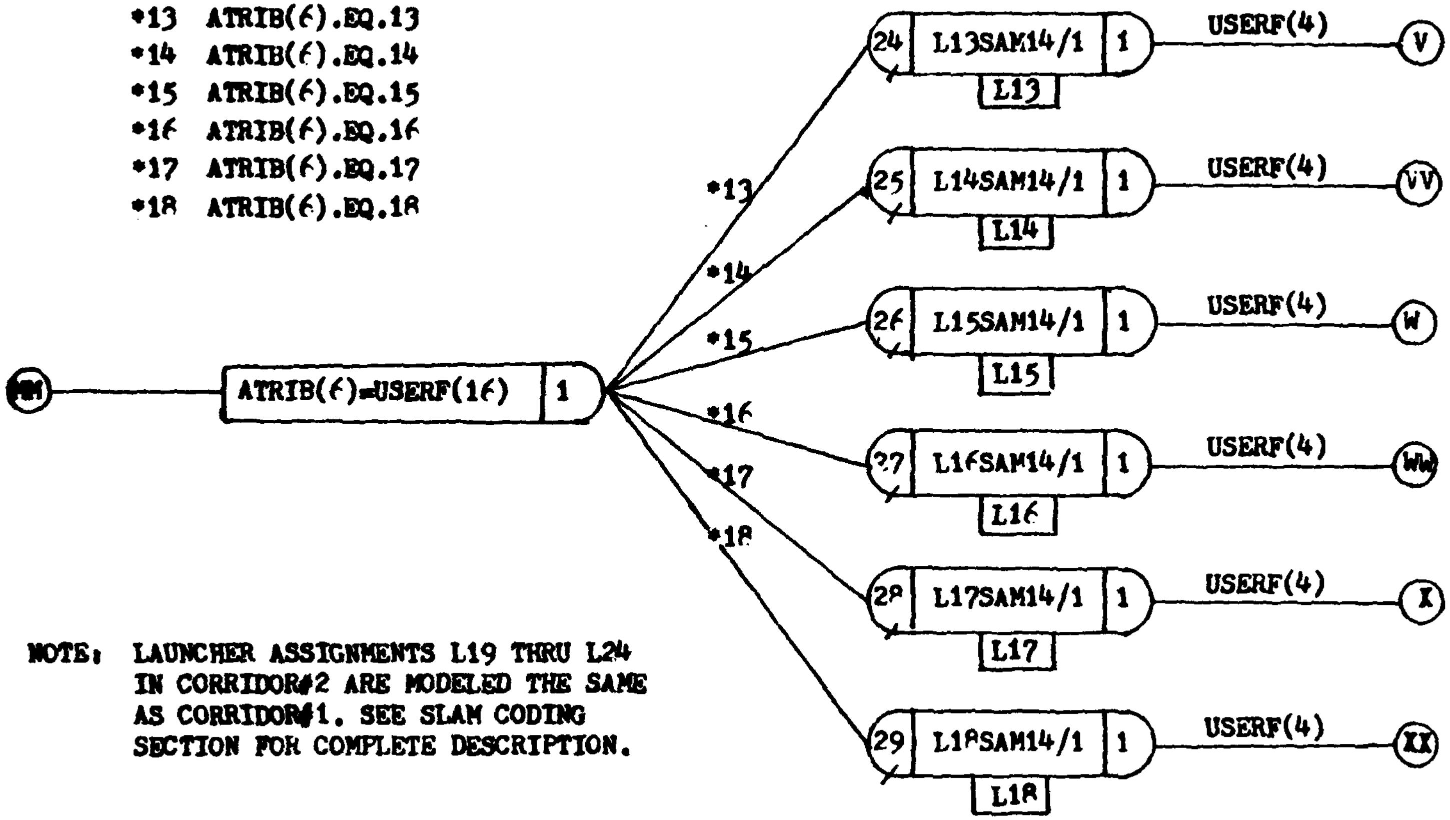
NOTE: N AND O ARE CORRIDOR #2 ZONE ASSIGNMENTS. SEE SLAM CODING SECTION FOR COMPLETE DETAILS


K
L
M
AAA
BBB
ATRIB(6)
TG12
TG13
TG14
SAM12/1
SAM13/1
SAM14/1
TS12
TS13
TS14
ES12
ES13
ES14
ATRIB(8)-TNOW
KK
LL
MM
ZZ

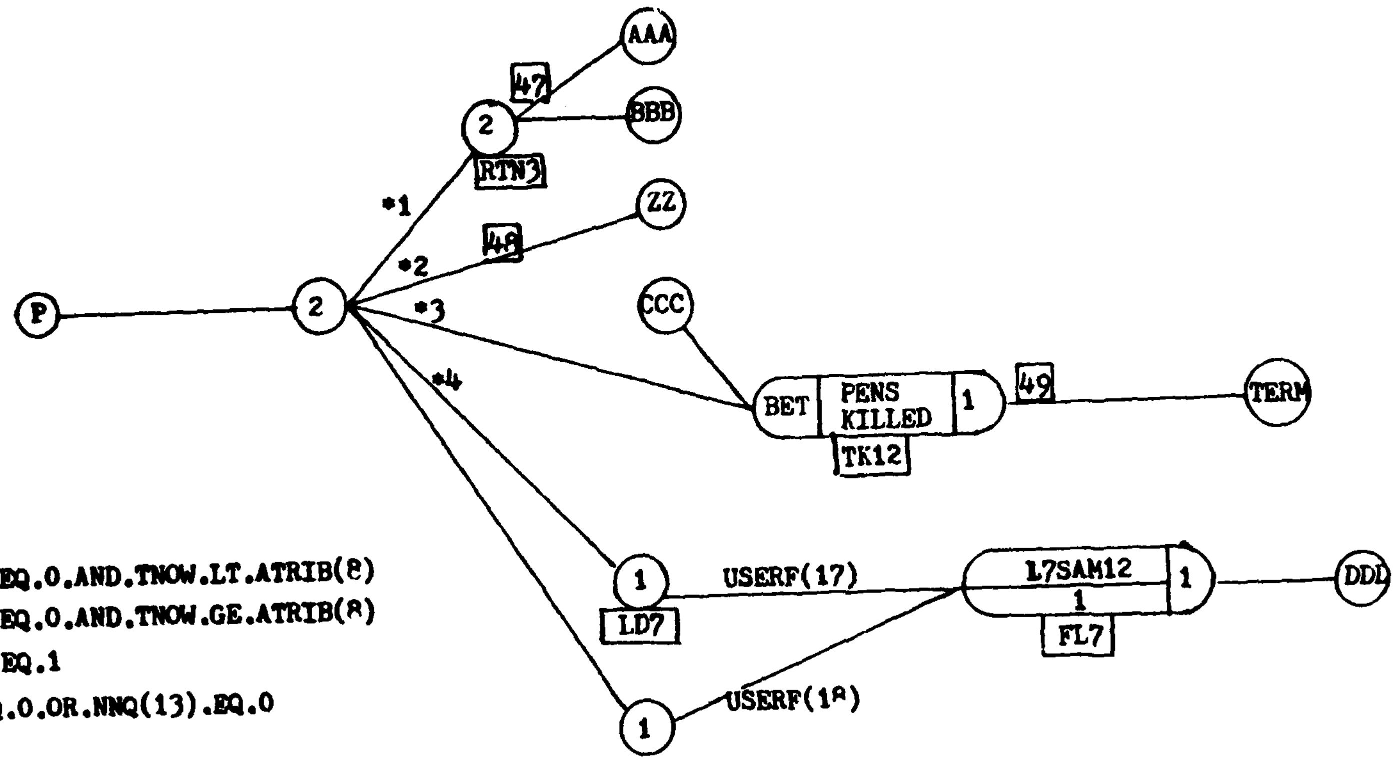


KK
ATRIB(6)=USERF(16)
1
*7
*8
*9
18
L7SAM12/1
1
L7
19
L8SAM12/1
1
L8
20
L9SAM12/1
1
L9
USERF(4)
USERF(4)
USERF(4)
P
Q
R
LL
ATRIB(6)=USERF(16)
1
*10
*11
*12
21
L10SAM13/1
1
L10
22
L11SAM13/1
1
L11
23
L12SAM13/1
1
L12
USERF(4)
USERF(4)
USERF(4)
S
T
U
*7 ATRIB(6).EQ.7
*8 ATRIB(6).EQ.8
*9 ATRIB(6).EQ.9
*10 ATRIB(6).EQ.10
*11 ATRIB(6).EQ.11
*12 ATRIB(6).EQ.12

*13 ATRIB(6).EQ.13
*14 ATRIB(6).EQ.14
*15 ATRIB(6).EQ.15
*16 ATRIB(6).EQ.16
*17 ATRIB(6).EQ.17
*18 ATRIB(6).EQ.18



NOTE: LAUNCHER ASSIGNMENTS L19 THRU L24 IN CORRIDOR#2 ARE MODELED THE SAME AS CORRIDOR#1. SEE SLAM CODING SECTION FOR COMPLETE DESCRIPTION.

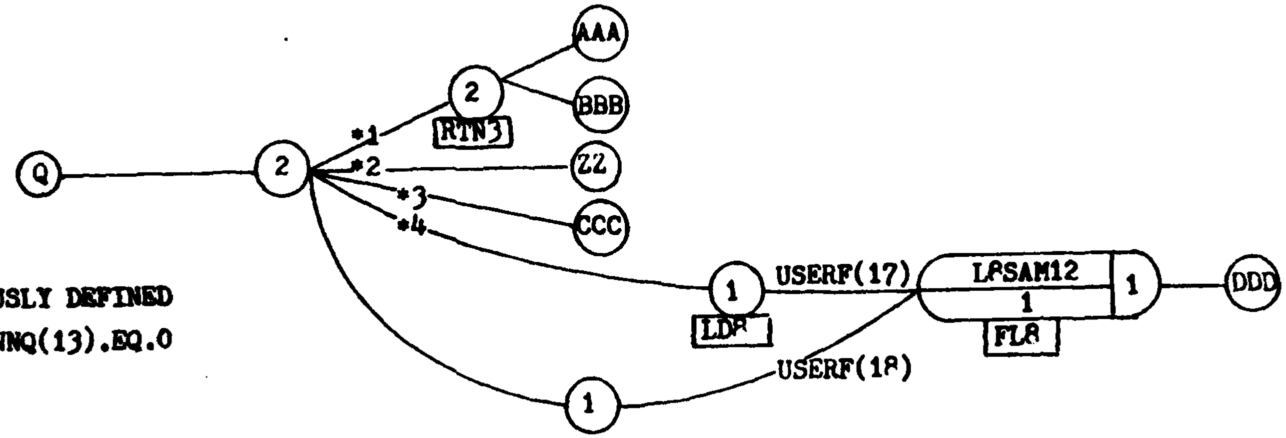


*1 ATRIB(5).EQ.0.AND.TNOW.LT.ATRIB(8)

*2 ATRIB(5).EQ.0.AND.TNOW.GE.ATRIB(8)

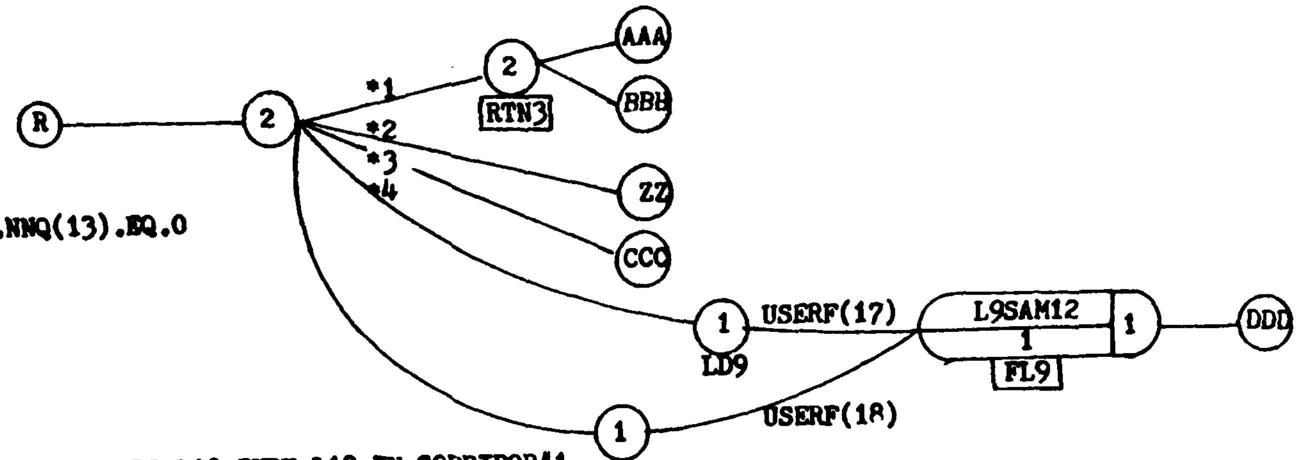
*3 ATRIB(5).EQ.1

*4 XX(51).EQ.0.OR.NNQ(13).EQ.0



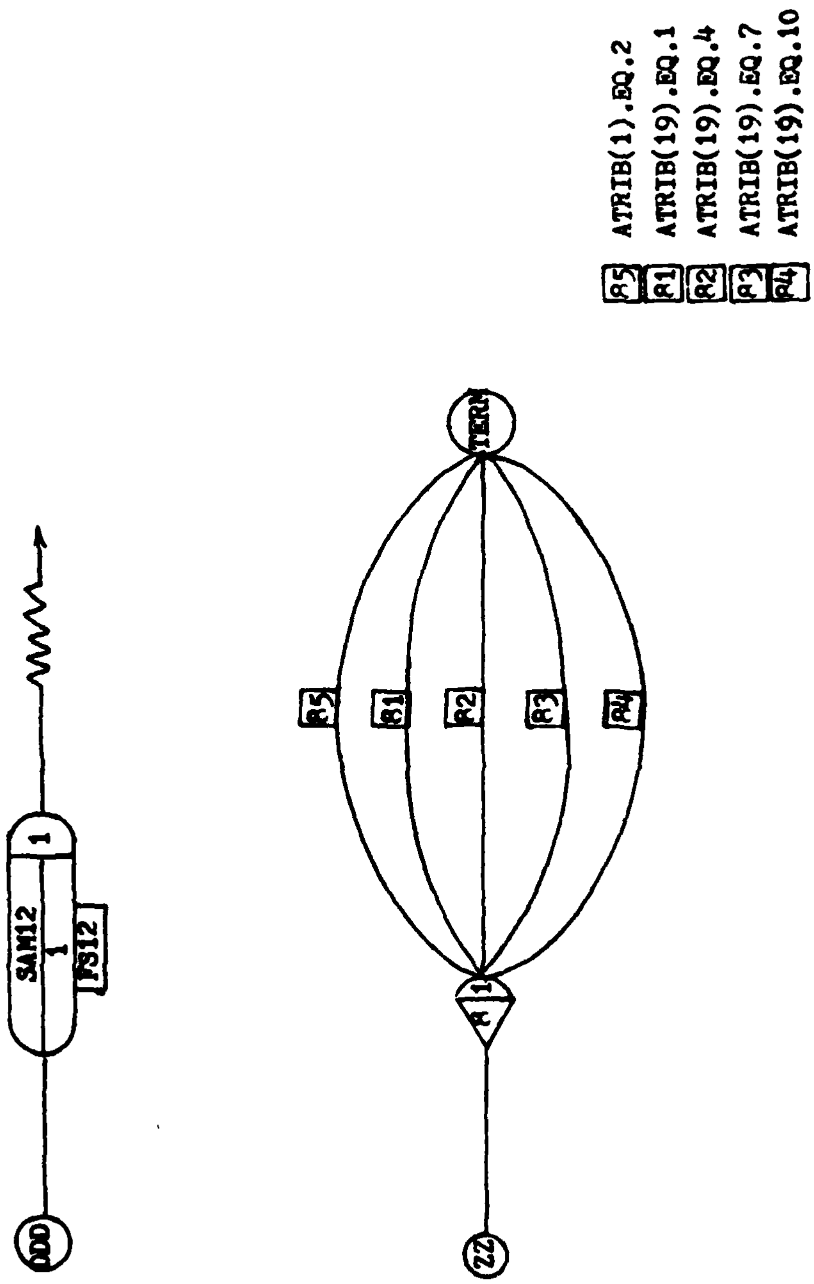
*1,*2,AND *3 PREVIOUSLY DEFINED

*4 XX(52).EQ.0.OR.NNQ(13).EQ.0



*4 XX(53).EQ.0.OR.NNQ(13).EQ.0

NOTE: THE REMAINING LAUNCHERS, L10 THRU L18, IN CORRIDOR#1 ARE MODELED SAME AS P Q AND R. ALSO, CORRIDOR#2 LAUNCHERS, L18 THRU L24 ARE LIKEWISE MODELED AS CORRIDOR#1. SEE SLAM CODING SECTION FOR COMPLETE DESCRIPTION.


DDD
SAM12
1
1
FS12
ZZ
A
1
R5
R1
R2
R3
R4
TERM
R5 ATRIB(1).EQ.2
R1 ATRIB(19).EQ.1
R2 ATRIB(19).EQ.4
R3 ATRIB(19).EQ.7
R4 ATRIB(19).EQ.10

APPENDIX B

SLAM COMPUTER MODEL

```
GJF91,CM167700,T700,10250.  T820050,FERGAL,4562
ATTACH,PROCFIL,ID=A810171,SN=ASDAD.
BEGIN,NOSFILE.
GET,FORT9,ID=T820050.
REWIND,FORT9.
ATTACH,PROCFIL,SLAMPROC,ID=AFIT.
BEGIN,SLAM,,M=FORT9,PL=10000.
SAVE,TAPE69=DAT55,ID=T820050.
EXIT,S.
REPL,DAT55,ID=T820050.
GEN,FERGAL,DILUTE,1/20/82,90,YES,NO,YES,NO,NO;
LIMITS,35,24,600;
PRIORITY/1,LVF(8)/2,LVF(8)/13,LVF(8)/14,LVF(8)/15,LVF(8);
PRIORITY/16,LVF(8)/17,LVF(8);
TIMST,XX(26),NO.EW/GCI SITES;
INTLC,XX(1)=10.,XX(3)=300.,XX(4)=1.,XX(5)=200.,XX(11)=100.;
INTLC,XX(13)=300.,XX(14)=4.,XX(15)=200.,XX(33)=3.,XX(34)=.3;
INTLC,XX(2)=10.,XX(12)=100.;
INTLC,XX(46)=.75,XX(47)=.25;
NETWORK;
     RESOURCE/SAMX1(3),1;
     RESOURCE/SAMX2(3),2;
     RESOURCE/L1SAMX1(1),3;
     RESOURCE/L2SAMX1(1),4;
     RESOURCE/L3SAMX1(1),5;
     RESOURCE/L4SAMX2(1),6;
     RESOURCE/L5SAMX2(1),7;
     RESOURCE/L6SAMX2(1),8;  LAUNCHER 3 BSAM02
     RESOURCE/DUMMY(0),9;
     RESOURCE/AI(40),10;
     RESOURCE/AI1(0),11;
     RESOURCE/AI2(40),12;
     RESOURCE/SAM12(3),13;
     RESOURCE/SAM13(3),14;
     RESOURCE/SAM14(6),15;
     RESOURCE/SAM23(3),16;
     RESOURCE/SAM22(3),17;
     RESOURCE/L7SAM12(1),18;
     RESOURCE/L8SAM12(1),19;
     RESOURCE/L9SAM12(1),20;
     RESOURCE/L10SAM13(1),21;
     RESOURCE/L11SAM13(1),22;
     RESOURCE/L12SAM13(1),23;
     RESOURCE/L13SAM14(1),24;
     RESOURCE/L14SAM14(1),25;
     RESOURCE/L15SAM14(1),26;
     RESOURCE/L16SAM14(1),27;
     RESOURCE/L17SAM14(1),28;
     RESOURCE/L18SAM14(1),29;
     RESOURCE/L19SAM23(1),30;
```

```
            RESOURCE/L20SAM23(1),31;
            RESOURCE/L21SAM23(1),32;
            RESOURCE/L22SAM22(1),33;
            RESOURCE/L23SAM22(1),34;
            RESOURCE/L24SAM22(1),35;
            CREATE,RLOGN(XX(33),XX(46)),0.,20,20,1;  BOMBER ARRIVALS
            ACT/1;
            GOON,1;
            ACT,,NNCNT(1).GT.XX(1),TM1;
            ACT,,NNCNT(1).EQ.1,INT1;
            ACT,,NNCNT(1).LE.XX(1),ASN1;
      TM1   TERMINATE;
      INT1  EVENT,1,1;
      ASN1  ASSIGN,ATRIB(1)=1.,ATRIB(2)=XX(3),ATRIB(3)=XX(4),
                    ATRIB(4)=XX(5),ATRIB(11)=1.,ATRIB(15)=1.,1;
               ACT/90;
      TGT1  EVENT,9,1;
               ACT,,,BAR1;
            CREATE,RNORM(XX(34),XX(47)),.1,20,200,1;  ALCM ARRIVALS
            ACT/2;
            GOON,1;
            ACT,,NNCNT(2).GT.XX(11),TM2;
            ACT,,NNCNT(2).EQ.1,INT2;
            ACT,,NNCNT(2).LE.XX(11),ASN2;
      TM2   TERMINATE;
      INT2  EVENT,1,1;
      ASN2  ASSIGN,ATRIB(1)=2,ATRIB(2)=XX(13),ATRIB(3)=XX(14),
           ATRIB(4)=XX(15),ATRIB(15)=1.,ATRIB(11)=USERF(9),1;
               ACT/91,,ATRIB(11).EQ.1.,TGT2;
               ACT/92,,ATRIB(11).EQ.2.,TGT2;
               ACT/93,,ATRIB(11).EQ.3.,TGT2;
               ACT/94,,ATRIB(11).EQ.4.,TGT2;
      TGT2  EVENT,10,1;
               ACT,,,BAR1;
      BAR1  GOON,1;
            ACT/10;
            ASSIGN,ATRIB(10)=NNCNT(10),ATRIB(17)=USERF(1),1;
            ACT/78,ATRIB(8)-TNOW,ATRIB(5).LT.1,FTR;
            ACT/5,,ATRIB(5).EQ.1;
            GOON,2;
            ACT,ATRIB(6),,SAM1;
            ACT,,,ESC1;
      SAM1  AWAIT(1),SAMX1/1,1;
            EVENT,3,1;
            ASSIGN,ATRIB(6)=USERF(12),1;
            ACT,,ATRIB(6).EQ.1,L1;
            ACT,,ATRIB(6).EQ.2,L2;
            ACT,,ATRIB(6).EQ.3,L3;
      L1    AWAIT(3),L1SAMX1/1,1;
            ACT,USERF(4);
```

```
            GOON,2;
            ACT,,ATRIB(5).EQ.0.AND.TNOW.LT.ATRIB(8),RTN1;
            ACT/17,,ATRIB(5).EQ.0.AND.TNOW.GE.ATRIB(8),FTR;
            ACT,,ATRIB(5).EQ.1,KIL1;
            ACT,,XX(19).EQ.0.OR.NNQ(1).EQ.0,LD1;
            ACT;
            GOON,1;
            ACT,USERF(18),,FL1;
     RTN1   GOON,2;
            ACT/11,,,SAM1;
            ACT,,,ESC1;
     KIL1   COLCT,BETWEEN,PENS KILLED SAM1,,,,2;
            ACT/7,,ATRIB(1).EQ.1,BK1;
            ACT/8,,ATRIB(1).EQ.2,CMK1;
     BK1    COLCT,BETWEEN,BMBR KILLS SAM1,,,,1;
            ACT,,,TMS1;
     CMK1   COLCT,BETWEEN,CM KILLS SAM1,,,,1;
            ACT,,,TMS1;
     TMS1   TERMINATE;
     LD1    GOON,1;
            ACT,USERF(2);
     FL1    FREE,L1SAMX1/1,1;
            ACT,,,FRS1;
     C
     L2     AWAIT(4),L2SAMX1/1,1;
            ACT,USERF(4);
            GOON,2;
            ACT,,ATRIB(5).EQ.0.AND.TNOW.LT.ATRIB(8),RTN1;
            ACT/18,,ATRIB(5).EQ.0.AND.TNOW.GE.ATRIB(8),FTR;
            ACT,,ATRIB(5).EQ.1,KIL1;
            ACT,,XX(20).EQ.0.OR.NNQ(1).EQ.0,LD2;
            ACT;
            GOON,1;
            ACT,USERF(18),,FL2;
     LD2    GOON,1;
            ACT,USERF(2);
     FL2    FREE,L2SAMX1/1,1;
            ACT,,,FRS1;
     C
     L3     AWAIT(5),L3SAMX1/1,1;
            ACT,USERF(4);
            GOON,2;
            ACT,,ATRIB(5).EQ.0.AND.TNOW.LT.ATRIB(8),RTN1;
            ACT/19,,ATRIB(5).EQ.0.AND.TNOW.GE.ATRIB(8),FTR;
            ACT,,ATRIB(5).EQ.1,KIL1;
            ACT,,XX(21).EQ.0.OR.NNQ(1).EQ.0,LD3;
            ACT;
            GOON,1;
            ACT,USERF(18),,FL3;
     LD3    GOON,1;
```

```
              ACT,USERF(2);
        FL3   FREE,L3SAMX1/1,1;
              ACT,,,FRS1;
        FRS1  FREE,SAMX1/1,1;
              TERMINATE;
        ESC1  GOON,1;
              ACT/9,ATRIB(8)-TNOW;
              EVENT,11,1;
              ACT,,,FTR;
        C
        C
        C
        C
              CREATE,RLOGN(XX(33),XX(46)),.3,20,20,1;   BOMBER ARRIVALS
              ACT/3;
              GOON,1;
              ACT,,NNCNT(3).GT.XX(2),TM3;
              ACT,,NNCNT(3).LE.XX(2),ASN3;
        TM3   TERMINATE;
        ASN3  ASSIGN,ATRIB(1)=1.,ATRIB(2)=XX(3),ATRIB(3)=XX(4),
                       ATRIB(4)=XX(5),ATRIB(11)=1.,ATRIB(15)=2.,1;
                 ACT/95;
        TGT3  EVENT,9,1;
                 ACT,,,BAR2;
              CREATE,RNORM(XX(34),XX(47)),.2,20,200,1;
              ACT/4;
              GOON,1;
              ACT,,NNCNT(4).GT.XX(12),TM4;
              ACT,,NNCNT(4).LE.XX(12),ASN4;
        TM4   TERMINATE;
        ASN4  ASSIGN,ATRIB(1)=2.,ATRIB(2)=XX(13),ATRIB(3)=XX(14),
                       ATRIB(4)=XX(15),ATRIB(15)=2.,ATRIB(11)=USERF(3),1;
                 ACT/96,,ATRIB(11).EQ.1.,TGT4;
                 ACT/97,,ATRIB(11).EQ.2.,TGT4;
                 ACT/98,,ATRIB(11).EQ.3.,TGT4;
                 ACT/99,,ATRIB(11).EQ.4.,TGT4;
        TGT4  EVENT,10,1;
                 ACT,,,BAR2;
        BAR2  GOON,1;
              ACT/12;
              ASSIGN,ATRIB(10)=NNCNT(12)+1000.,ATRIB(17)=USERF(1),1;
                 ACT/79,ATRIB(8)-TNOW,ATRIB(5).EQ.0.,FTR;
                 ACT/6,,ATRIB(5).EQ.1.;
              GOON,2;
                 ACT,ATRIB(6),,SAM2;
                 ACT,,,ESC2;
        SAM2  AWAIT(2),SAMX2/1,1;
              EVENT,3,1;
              ASSIGN,ATRIB(6)=USERF(12),1;
                 ACT,,ATRIB(6).EQ.4.,L4;
```

```
               ACT,,ATRIB(6).EQ.5.,L5;
               ACT,,ATRIB(6).EQ.6.,L6;
      L4    AWAIT(6),L4SAMX2/1,1;
               ACT,USERF(4);
            GOON,2;
               ACT,,ATRIB(5).EQ.0. .AND. TNOW.LT.ATRIB(8),RTN2;
               ACT/22,,ATRIB(5).EQ.0. .AND. TNOW.GE.ATRIB(8),FTR; PEN ESC
               ACT,,ATRIB(5).EQ.1.,KIL2;
               ACT,,II(22).EQ.0. .OR. NNQ(2).EQ.0 ,LD4;
               ACT;
            GOON,1;
               ACT,USERF(18),,FL4 ;
      RTN2  GOON,2;
               ACT/21,,,SAM2;
               ACT,,,ESC2;
      KIL2  COLCT,BETWEEN,PENS KILLED SAM2,,,,2;
               ACT/25,,ATRIB(1).EQ.1.,BK2;
               ACT/26,,ATRIB(1).EQ.2.,CMK2;
      BK2   COLCT,BETWEEN,BMBR KILLS SAM2,,,,1;
               ACT,,,TMS2;
      CMK2  COLCT,BETWEEN,CM KILLS SAM2,,,,1;
               ACT,,,TMS2;
      TMS2  TERMINATE;
      LD4   GOON,1;
               ACT,USERF(2);       RELOAD LAUNCHER 1,BSAM#2
      FL4   FREE,L4SAMX2/1,1;    RELEASE LAUNCHER 1
               ACT,,,FRS2;       RELEASE A SAM CHANNEL ON BSAM#2
      C
      L5    AWAIT(7),L5SAMX2/1,1;
               ACT,USERF(4);
            GOON,2;
               ACT,,ATRIB(5).EQ.0. .AND. TNOW.LT.ATRIB(8),RTN2;
               ACT/23,,ATRIB(5).EQ.0. .AND. TNOW .GE. ATRIB(8),FTR;
               ACT,,ATRIB(5).EQ.1.,KIL2;
               ACT,,II(23).EQ.0. .OR. NNQ(2).EQ.0 ,LD5;
               ACT;
            GOON,1;
               ACT,USERF(18),,FL5 ;
      LD5   GOON,1;
               ACT,USERF(2);
      FL5   FREE,L5SAMX2/1,1;   FREE LAUNCHER 5 BSAM#2
               ACT,,,FRS2;        GO TO A FREE SAM CHANNEL NODE
      C
      L6    AWAIT(8),L6SAMX2/1,1;
               ACT,USERF(4);
            GOON,2;
               ACT,,ATRIB(5).EQ.0. .AND. TNOW.LT.ATRIB(8),RTN2;
               ACT/24,,ATRIB(5).EQ.0. .AND. TNOW.GE.ATRIB(8),FTR;
               ACT,,ATRIB(5).EQ.1.,KIL2;
               ACT,,II(24).EQ.0. .OR. NNQ(2).EQ.0,LD6;
```

```
               ACT;
          GOON,1;
               ACT,USERF(18),,FL6 ;
     LD6  GOON,1;
               ACT,USERF(2);
     FL6  FREE,L6SAMX2/1,1;
                    ACT,,,FRS2;
     FRS2 FREE,SAMX2/1,1;      FREE A SAM CHANNEL IN BSAM#2
          TERMINATE;
     ESC2 GOON,1;
               ACT/20,ATRIB(8)-TNOW;
          EVENT,12,1;
          ACT,,,FTR;
     FTR  GOON,1;
          ACT/13,,ATRIB(11).EQ.1,Z1;
          ACT/14,,ATRIB(11).NE.1,ASN5;
     Z1   EVENT,2,1;
          ACT/15,,ATRIB(1).EQ.2,TM10;
          ACT/16,,ATRIB(1).EQ.1,ASN5;
     TM10 TERMINATE;
     ASN5 ASSIGN,ATRIB(12)=USERF(5),ATRIB(13)=USERF(6),
               ATRIB(14)=USERF(7),1;
     ASN6 ASSIGN,ATRIB(18)=USERF(8),ATRIB(9)=TNOW+ATRIB(18),
               ATRIB(19)=ATRIB(9)+XX(48),1;
          GOON,1;
          ACT/27,ATRIB(14)-TNOW,ATRIB(9).GE.ATRIB(14),TMZN;
          ACT/33,,ATRIB(9).LT.ATRIB(14);
          GOON,2;
          ACT,ATRIB(18),,FCAP;
          ACT/28,ATRIB(14)-TNOW;
          EVENT,4,1;
          ACT,,,TMZN
     FCAP AWAIT(10),AI/1,1;
          EVENT,3,1;
          ASSIGN,ATRIB(16)=USERF(13),1;
               ACT,,ATRIB(16).EQ.1.,CAP1;
               ACT,,ATRIB(16).EQ.2.,CAP2;
     CAP1 AWAIT(11),AI1/1,1;
               ACT,USERF(10),,AIC;
     CAP2 AWAIT(12),AI2/1,1;
               ACT,USERF(10),,AIC;
     AIC  GOON,2;
          ACT/76,,ATRIB(5).EQ.0.,ASN6;
          ACT/29,,ATRIB(5).EQ.1,AIK;
          ACT/30,,ATRIB(16).EQ.0.,RTB;
          ACT/31,,ATRIB(16).EQ.1.,R1;
          ACT/32,,ATRIB(16).EQ.2.,R2;
     RTB  GOON,1;
               ACT,USERF(14),,MSL0;
     R1   GOON,1;
```

```
          ACT,USERF(15),,MSL1;
R2     GOON,1;
          ACT,USERF(15),,MSL2;
MSLØ   FREE,AI2/1,1;
       ACT,,,FRAI;
MSL1   ALTER,AI1/1,1;
       ACT,,,FRAI;
MSL2   FREE,AI2/1,1;
       ACT,,,FRAI;
FRAI   FREE,AI/1,1;
       TERMINATE;
C
AIK    COLCT,BETWEEN,PENS KILLED AI,,,,2;
       ACT/34,,ATRIB(1).EQ.1.,AIBK;
       ACT/35,,ATRIB(1).EQ.2.,AICK;
AIBK   COLCT,BETWEEN,BMBR KILLS AI,,,,1;
       ACT,,,ZZ;
AICK   COLCT,BETWEEN,CM KILLS AI,,,,1;
       TERMINATE;
TMZN   ASSIGN,ATRIB(17)=USERF(1),1;
          ACT/77,ATRIB(8)-TNOW,ATRIB(5).EQ.Ø.,ZZ;
          ACT/37,,ATRIB(15).EQ.1 .AND. ATRIB(11).EQ.2,TG12;
          ACT/38,,ATRIB(15).EQ.1 .AND. ATRIB(11).EQ.3,TG13;
          ACT/39,,ATRIB(1).EQ.1  .OR.  ATRIB(11).EQ.4,TG14;
          ACT/4Ø,,ATRIB(15).EQ.2 .AND. ATRIB(11).EQ.3,TG23;
          ACT/41,,ATRIB(15).EQ.2 .AND. ATRIB(11).EQ.2,TG22;
TG12   GOON,2;
          ACT,ATRIB(6),,TS12;
          ACT,,,ES12;
TS12   AWAIT(13),SAM12/1,1;
       EVENT,3,1;
       ASSIGN,ATRIB(6)=USERF(16),1;
          ACT,,ATRIB(6).EQ.7,L7;
          ACT,,ATRIB(6).EQ.8,L8;
          ACT,,ATRIB(6).EQ.9,L9;
L7     AWAIT(18),L7SAM12/1,1;
          ACT,USERF(4);
       GOON,2;
          ACT,,ATRIB(5).EQ.Ø .AND. TNOW.LT.ATRIB(8),RTN3;
          ACT/48,,ATRIB(5).EQ.Ø .AND. TNOW.GE.ATRIB(8),ZZ;
          ACT,,ATRIB(5).EQ.1,TK12;
          ACT,,XX(51).EQ.Ø .OR. NNQ(13).EQ.Ø,LD7;
          ACT;
       GOON,1;
          ACT,USERF(18),,FL7;
RTN3   GOON,2;
          ACT/47,,,TS12;
          ACT,,,ES12;
TK12   COLCT,BETWEEN,PENS KILLED TS12,,,,1;
          ACT/49;
```

```
          TERMINATE;
LD7       GOON,1;
             ACT,USERF(17);
FL7       FREE,L7SAM12/1,1;
             ACT,,,FS12;
C
L8        AWAIT(19),L8SAM12/1,1;
             ACT,USERF(4);
          GOON,2;
             ACT,,ATRIB(5).EQ.0 .AND. TNOW.LT.ATRIB(8),RTN3
             ACT/50,,ATRIB(5).EQ.0 .AND. TNOW.GE.ATRIB(8),ZZ;
             ACT,,ATRIB(5).EQ.1,TK12;
             ACT,,II(52).EQ.0 .OR.NNQ(13).EQ.0,LD8;
             ACT;
          GOON,1;
             ACT,USERF(18),,FL8;
LD8       GOON,1;
             ACT,USERF(17);
FL8       FREE,L8SAM12/1,1;
             ACT,,,FS12;
C
L9        AWAIT(20),L9SAM12/1,1;
             ACT,USERF(4);
          GOON,2;
             ACT,,ATRIB(5).EQ.0 .AND. TNOW.LT.ATRIB(8),RTN3;
             ACT/51,,ATRIB(5).EQ.0 .AND. TNOW.GE.ATRIB(8),ZZ;
             ACT,,ATRIB(5).EQ.1,TK12;
             ACT,,II(53).EQ.0 .OR. NNQ(13).EQ.0,LD9;
             ACT;
          GOON,1;
             ACT,USERF(18),,FL9;
LD9       GOON,1;
             ACT,USERF(17);
FL9       FREE,L9SAM12/1,1;
             ACT,,,FS12;
C
FS12      FREE,SAM12/1,1;
          TERMINATE;
ES12      GOON,1;
             ACT/42,ATRIB(8)-TNOW;
          EVENT,13,1;
             ACT,,,ZZ;
C
C
C
TG13      GOON,2;
             ACT,ATRIB(6),,TS13;
          ACT,,,ES13;
TS13      AWAIT(14),SAM13/1,1;
          EVENT,3,1;
```

```
      ASSIGN,ATRIB(6)=USERF(16),1;
        ACT,,ATRIB(6).EQ.10,L10;
        ACT,,ATRIB(6).EQ.11,L11;
        ACT,,ATRIB(6).EQ.12,L12;
L10   AWAIT(21),L10SAM13/1,1;
        ACT,USERF(4);
      GOON,2;
        ACT,,ATRIB(5).EQ.0 .AND. TNOW.LT.ATRIB(8),RTN4;
        ACT/52,,ATRIB(5).EQ.0 .AND. TNOW.GE.ATRIB(8),ZZ;
        ACT,,ATRIB(5).EQ.1,TK13;
        ACT,,II(54).EQ.0 .OR. NNQ(14).EQ.0,LD10;
        ACT;
      GOON,1;
        ACT,USERF(18),,FL10;
RTN4  GOON,2;
        ACT/53,,,TS13;
        ACT,,,ES13;
TK13  COLCT,BETWEEN,PENS KILLED TS13,,,,1;
        ACT/54;
      TERMINATE;
LD10  GOON,1;
        ACT,USERF(17);
FL10  FREE,L10SAM13/1,1;
        ACT,,,FS13;
C
L11   AWAIT(22),L11SAM13/1,1;
        ACT,USERF(4);
      GOON,2;
        ACT,,ATRIB(5).EQ.0 .AND. TNOW.LT.ATRIB(8),RTN4;
        ACT/55,,ATRIB(5).EQ.0 .AND. TNOW.GE.ATRIB(8),ZZ;
        ACT,,ATRIB(5).EQ.1,TK13;
        ACT,,II(55).EQ.0 .OR. NNQ(14).EQ.0,LD11;
        ACT;
      GOON,1;
        ACT,USERF(18),,FL11;
LD11  GOON,1;
        ACT,USERF(17);
FL11  FREE,L11SAM13/1,1;
        ACT,,,FS13;
C
L12   AWAIT(23),L12SAM13/1,1;
        ACT,USERF(4);
      GOON,2;
        ACT,,ATRIB(5).EQ.0 .AND. TNOW.LT.ATRIB(8),RTN4;
        ACT/56,,ATRIB(5).EQ.0 .AND. TNOW.GE.ATRIB(8),ZZ;
        ACT,,ATRIB(5).EQ.1,TK13;
        ACT,,II(56).EQ.0 .OR. NNQ(14).EQ.0,LD12;
        ACT;
      GOON,1;
        ACT,USERF(18),,FL12;
```

```
LD12  GOON,1;
         ACT,USERF(17);
FL12  FREE,L12SAM13/1,1;
         ACT,,,FS13;
C
FS13  FREE,SAM13/1,1;
      TERMINATE;
ES13  GOON,1;
         ACT/43,ATRIB(8)-TNOW;
      EVENT,14,1;
         ACT,,,ZZ;
TG14  GOON,2;
         ACT,ATRIB(6),,TS14;
         ACT,,,ES14;
TS14  AWAIT(15),SAM14/1,1;
      EVENT,3,1;
      ASSIGN,ATRIB(6)=USERF(16),1;
         ACT,,ATRIB(6).EQ.13,L13;
         ACT,,ATRIB(6).EQ.14,L14;
         ACT,,ATRIB(6).EQ.15,L15;
         ACT,,ATRIB(6).EQ.16,L16;
         ACT,,ATRIB(6).EQ.17,L17;
         ACT,,ATRIB(6).EQ.18,L18;
L13   AWAIT(24),L13SAM14/1,1;
         ACT,USERF(4);
      GOON,2;
         ACT,,ATRIB(5).EQ.0 .AND. TNOW.LT.ATRIB(8),RTN5;
         ACT/57,,ATRIB(5).EQ.0 .AND. TNOW.GE.ATRIB(8),ZZ;
         ACT,,ATRIB(5).EQ.1,TK14;
      ACT,,XX(57).EQ.0 .OR. NNQ(15).EQ.0,LD13;
         ACT;
      GOON,1;
         ACT,USERF(18),,FL13;
RTN5  GOON,2;
         ACT/58,,,TS14;
         ACT,,,ES14;
TK14  COLCT,BETWEEN,PENS KILLED TS14,,,,1;
         ACT/59,,ATRIB(1).EQ.1,BKT4;
         ACT/60,,ATRIB(1).EQ.2,CKT4;
BKT4  COLCT,BETWEEN,BOMBERS KILLED TS14,,,,1;
         ACT,,,ZZ;
CKT4  COLCT,BETWEEN,CMS KILLED TS14,,,,1;
      TERMINATE;
LD13  GOON,1;
         ACT,USERF(17);
FL13  FREE,L13SAM14/1,1;
         ACT,,,FS14;
C
L14   AWAIT(25),L14SAM14/1,1;
         ACT,USERF(4);
```

```
           GOON,2;
              ACT,,ATRIB(5).EQ.0 .AND. TNOW.LT.ATRIB(8),RTN5;
              ACT/61,,ATRIB(5).EQ.0 .AND. TNOW.GE.ATRIB(8),ZZ;
              ACT,,ATRIB(5).EQ.1,TK14;
              ACT,,II(58).EQ.0 .OR.  NNQ(15).EQ.0,LD14;
              ACT;
           GOON,1;
              ACT,USERF(18),,FL14;
LD14       GOON,1;
              ACT,USERF(17);
FL14       FREE,L14SAM14/1,1;
              ACT,,,FS14;
C
L15        AWAIT(26),L15SAM14/1,1;
              ACT,USERF(4);
           GOON,2;
              ACT,,ATRIB(5).EQ.0 .AND. TNOW.LT.ATRIB(8),RTN5;
              ACT/62,,ATRIB(5).EQ.0 .AND. TNOW.GE.ATRIB(8),ZZ;
              ACT,,ATRIB(5).EQ.1,TK14;
              ACT,,II(59).EQ.0 .OR. NNQ(15).EQ.0,LD15;
              ACT;
           GOON,1;
              ACT,USERF(18),,FL15;
LD15       GOON,1;
              ACT,USERF(17);
FL15       FREE,L15SAM14/1,1;
              ACT,,,FS14;
C
L16        AWAIT(27),L16SAM14/1,1;
              ACT,USERF(4);
           GOON,2;
              ACT,,ATRIB(5).EQ.0 .AND. TNOW.LT.ATRIB(8),RTN5;
              ACT/63,,ATRIB(5).EQ.0 .AND. TNOW.GE.ATRIB(8),ZZ;
              ACT,,ATRIB(5).EQ.1,TK14;
              ACT,,II(60).EQ.0 .OR. NNQ(15).EQ.0,LD16;
              ACT;
           GOON,1;
              ACT,USERF(18),,FL16;
LD16       GOON,1;
              ACT,USERF(17);
FL16       FREE,L16SAM14/1,1;
              ACT,,,FS14;
C
L17        AWAIT(28),L17SAM14/1,1;
              ACT,USERF(4);
           GOON,2;
              ACT,,ATRIB(5).EQ.0 .AND. TNOW.LT.ATRIB(8),RTN5;
              ACT/64,,ATRIB(5).EQ.0 .AND. TNOW.GE.ATRIB(8),ZZ;
              ACT,,ATRIB(5).EQ.1,TK14;
              ACT,,II(61).EQ.0 .OR. NNQ(15).EQ.0,LD17;
```

```
           ACT;
         GOON,1;
           ACT,USERF(18),,FL17;
LD17     GOON,1;
           ACT,USERF(17);
FL17     FREE,L17SAM14/1,1;
           ACT,,,FS14;
C
L18      AWAIT(29),L18SAM14/1,1;
           ACT,USERF(4);
         GOON,2;
           ACT,,ATRIB(5).EQ.0 .AND. TNOW.LT.ATRIB(8),RTN5;
           ACT/65,,ATRIB(5).EQ.0 .AND. TNOW.GE.ATRIB(8),ZZ;
           ACT,,ATRIB(5).EQ.1,TK14;
           ACT,,II(62).EQ.0 .OR. NNQ(15).EQ.0,LD18;
           ACT;
         GOON,1;
           ACT,USERF(18),,FL18;
LD18     GOON,1;
           ACT,USERF(17);
FL18     FREE,L18SAM14/1,1;
           ACT,,,FS14;
C
FS14     FREE,SAM14/1,1;
         TERMINATE;
ES14     GOON,1;
           ACT/44,ATRIB(8)-TNOW;
         EVENT,15,1;
           ACT,,,ZZ;
C
C
C
TC23     GOON,2;
           ACT,ATRIB(6),,TS23;
           ACT,,,ES23;
TS23     AWAIT(16),SAM23/1,1;
         EVENT,3,1;
         ASSIGN,ATRIB(6)=USERF(16),1;
           ACT,,ATRIB(6).EQ.19,L19;
           ACT,,ATRIB(6).EQ.20,L20;
           ACT,,ATRIB(6).EQ.21,L21;
L19      AWAIT(30),L19SAM23/1,1;
           ACT,USERF(4);
         GOON,2;
           ACT,,ATRIB(5).EQ.0 .AND. TNOW.LT.ATRIB(8),RTN6;
           ACT/66,,ATRIB(5).EQ.0 .AND. TNOW.GE.ATRIB(8),ZZ;
           ACT,,ATRIB(5).EQ.1,TK23;
           ACT,,II(63).EQ.0 .OR. NNQ(16).EQ.0,LD19;
           ACT;
         GOON,1;
```

```
                ACT,USERF(18),,FL19;
        RTN6  GOON,2;
                ACT/67,,,TS23;
                ACT,,,ES23;
        TK23  COLCT,BETWEEN,PENS KILLED TS23,,,,1;
                ACT/68;


              TERMINATE;
        LD19  GOON,1;
                ACT,USERF(17);
        FL19  FREE,L19SAM23/1,1;
                ACT,,,FS23;
        C
        L20   AWAIT(31),L20SAM23/1,1;
                ACT,USERF(4);
              GOON,2;
                ACT,,ATRIB(5).EQ.0 .AND. TNOW.LT.ATRIB(8),RTN6;
                ACT/69,,ATRIB(5).EQ.0 .AND. TNOW.GE.ATRIB(8),ZZ;
                ACT,,ATRIB(5).EQ.1,TK23;
                ACT,,II(64).EQ.0 .OR. NNQ(16).EQ.0,LD20;
                ACT;
              GOON,1;
                ACT,USERF(18),,FL20;
        LD20  GOON,1;
                ACT,USERF(17);
        FL20  FREE,L20SAM23/1,1;
                ACT,,,FS23;
        C
        L21   AWAIT(32),L21SAM23/1,1;
                ACT,USERF(4);
              GOON,2;
                ACT,,ATRIB(5).EQ.0 .AND. TNOW.LT.ATRIB(8),RTN6;
                ACT/70,,ATRIB(5).EQ.0 .AND. TNOW.GE.ATRIB(8),ZZ;
                ACT,,ATRIB(5).EQ.1,TK23;
                ACT,,II(65).EQ.0 .OR. NNQ(16).EQ.0,LD21;
                ACT;
              GOON,1;
                ACT,USERF(18),,FL21;
        LD21  GOON,1;
                ACT,USERF(17);
        FL21  FREE,L21SAM23/1,1;
                ACT,,,FS23;
        C
        FS23  FREE,SAM23/1,1;
              TERMINATE;
        ES23  GOON,1;
                ACT/45,ATRIB(8)-TNOW;
              EVENT,16,1;
                ACT,,,ZZ;
        C
        C
```

```
C
TC22  GOON,2;
         ACT,ATRIB(6),,TS22;
         ACT,,,ES22;
TS22  AWAIT(17),SAM22/1,1;
      EVENT,3,1;
      ASSIGN,ATRIB(6)=USERF(16),1;
         ACT,,ATRIB(6).EQ.22,L22;
         ACT,,ATRIB(6).EQ.23,L23;
         ACT,,ATRIB(6).EQ.24,L24;
L22   AWAIT(33),L22SAM22/1,1;
         ACT,USERF(4);
      GOON,2;
         ACT,,ATRIB(5).EQ.0 .AND. TNOW.LT.ATRIB(8),RTN7;
         ACT/71,,ATRIB(5).EQ.0 .AND. TNOW.GE.ATRIB(8),ZZ;
         ACT,,ATRIB(5).EQ.1,TK22;
         ACT,,XX(68).EQ.0 .OR. NNQ(17).EQ.0,LD22;
         ACT;
      GOON,1;
         ACT,USERF(18),,FL22;
RTN7  GOON,2;
         ACT/72,,,TS22;
         ACT,,,ES22;
TK22  COLCT,BETWEEN,PENS KILLED TS22,,,,1;
         ACT/73;
      TERMINATE;
LD22  GOON,1;
         ACT,USERF(17);
FL22  FREE,L22SAM22/1,1;
         ACT,,,FS22;
C
L23   AWAIT(34),L23SAM22/1,1;
         ACT,USERF(4);
      GOON,2;
         ACT,,ATRIB(5).EQ.0 .AND. TNOW.LT.ATRIB(8),RTN7;
         ACT/74,,ATRIB(5).EQ.0 .AND. TNOW.GE.ATRIB(8),ZZ;
         ACT,,ATRIB(5).EQ.1,TK22;
         ACT,,XX(69).EQ.0 .OR. NNQ(17).EQ.0,LD23;
         ACT;
      GOON,1;
         ACT,USERF(18),,FL23;
LD23  GOON,1;
         ACT,USERF(17);
FL23  FREE,L23SAM22/1,1;
         ACT,,,FS22;
C
L24   AWAIT(35),L24SAM22/1,1;
         ACT,USERF(4);
      GOON,2;
         ACT,,ATRIB(5).EQ.0 .AND. TNOW.LT.ATRIB(8),RTN7;
```

```
                ACT/75,,ATRIB(5).EQ.0 .AND. TNOW.GE.ATRIB(8),ZZ;
                ACT,,ATRIB(5).EQ.1,TK22;
                ACT,,XX(70).EQ.0 .OR. NNQ(17).EQ.0,LD24;
                ACT;
           GOON,1;
                ACT,USERF(18),,FL24;
     LD24  GOON,1;
                ACT,USERF(17);
     FL24  FREE,L24SAM22/1,1;
                ACT,,,FS22;
     C
     FS22  FREE,SAM22/1,1;
           TERMINATE;
     ES22  GOON,1;
                ACT/46,ATRIB(8)-TNOW;
           EVEN,17,1;
                ACT,,,ZZ;
     C
     C
     ZZ    EVENT,8,1;
                ACT/85,,ATRIB(1).EQ.2,TZZZ;
                ACT/81,,ATRIB(19).EQ.1,TZZZ;
                ACT/82,,ATRIB(19).EQ.4,TZZZ;
                ACT/83,,ATRIB(19).EQ.7,TZZZ;
                ACT/84,,ATRIB(19).EQ.10,TZZZ;
     TZZZ  TERMINATE;
           ENDNETWORK;
     INIT,0.,200.;
     SIMULATE;
     SIMULATE;
     SIMULATE;
     SIMULATE;
     SIMULATE;
     SIMULATE;
     SIMULATE;
     SIMULATE;
     SIMULATE;
     SIMULATE;
     INTLC,XX(4)=2.,XX(14)=5.
     SIMULATE;
     SIMULATE;
     SIMULATE;
     SIMULATE;
     SIMULATE;
     SIMULATE;
     SIMULATE;
     SIMULATE;
     SIMULATE;
     SIMULATE;
     INTLC,XX(4)=3.,XX(14)=6.
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SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
INTLC,XX(3)=600.,XX(13)=600.,XX(4)=1.,XX(14)=3.;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
INTLC,XX(4)=2.,XX(14)=5.;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
INTLC,XX(4)=3.,XX(14)=6.;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
INTLC,XX(3)=800.,XX(13)=800.,XX(4)=1.,XX(14)=3.;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
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SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
INTLC,XX(4)=2.,XX(14)=5.;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
INTLC,XX(4)=3.,XX(14)=6.;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
FIN;
```

APPENDIX C

FORTRAN COMPUTER MODEL

```
      PROGRAM MAIN(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE7)
     DIMENSION NSET(25000)
     COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,
    :            MSTOP,NCLNR,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,
    :            SS(100),SSL(100),TNEXT,TNOW,XX(100)
     COMMON/UCOM1/RCS(0:14,1:6),PDCIN(6),PDCOUT(6)
     COMMON/UCOM2/Z1(20),Z2(60),Z3(60),Z4(60)
     COMMON QSET(25000)
     EQUIVALENCE (NSET(1),QSET(1))
     OPEN(69,FILE='TAPE69')
     NNSET=25000
     NCRDR=5
     NPRNT=6
     NTAPE=7
     CALL SLAM
     STOP
     END
     SUBROUTINE INTLC
     COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,
    :            MSTOP,NCLNR,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,
    :            SS(100),SSL(100),TNEXT,TNOW,XX(100)
     COMMON/UCOM1/RCS(0:14,1:6),PDCIN(6),PDCOUT(6)
     COMMON/UCOM2/Z1(20),Z2(60),Z3(60),Z4(60)
     DATA((RCS(I,J),J=1,6),I=0,14)
    :       /18.,1.8,.18,.1,.01,.001,
    :        16.,1.6,.16,.08,.008,.0008,
    :        15.,1.5,.15,.07,.007,.0007,
    :        14.,1.4,.14,.06,.006,.0006,
    :        12.,1.2,.12,.05,.005,.0005,
    :        20.,2.0,.20,.10,.010,.0010,
    :        35.,3.5,.35,1.0,.10,.0100,
    :        40.,4.0,.40,1.3,.13,.013,
    :        500.,50.,5.0,6.0,.6,.06,
    :        2000.,200.,20.,25.,2.5,.25,
    :        500.,40.,4.0,6.0,.60,.06,
    :        40.,3.0,.30,1.3,.13,.013,
    :        20.,2.0,.20,1.0,.10,.010,
    :        50.,1.5,.15,.10,.01,.001,
    :        90.,1.0,.10,.05,.005,.0005/
     DATA  PDCIN/.900,.877,.804,.575,.494,.080/
     DATA PDCOUT/.822,.754,.500,.312,.155,.025/
     DATA Z1,Z2,Z3,Z4/200*1./
C
C  THE FOLLOWING IS A DESCRIPTIVE LIST OF THE GLOBAL VARIABLES
C  TO BE SET FOR ALL RUNS.  THESE MAY BE UPDATED FOR FURTHER
C  SENSITIVITY ANALYSIS.
C
C     XX(8)=THE CORRIDOR LIMITS ON THE BAND SAMS -
C        THIS IS A FUNCTION OF THE BAND SAM SITE DENSITY (NM)
         XX(8)=15.
```

```
C
C     THE FOLLOWING VARIABLES ARE THE INITIAL CONDITIONS
C     FOR THE LAUNCHERS. THEY ARE FULL WITH 4 MISSILES APIECE
C     AND A 3:1 RATIO FOR MISSILES IN READY STORAGE
C     XX(17)=MISSILES IN READY STORAGE BSAM #1
      XX(17)=36.
C     XX(18)=MISSILES IN READY STORAGE BSAM #2
      XX(18)=36.
C     XX(69)=MISSILES IN READY STORAGE TSAM #12
      XX(69)=36.
C     XX(70)=MISSILES  "  "     "     "   #13
      XX(70)=36.
C     XX(71)=MISSILES  "  "     "     "   #14
      XX(71)=36.
C     XX(72)=MISSILES  "  "     "     "   #22
      XX(72)=36.
C     XX(73)=MISSILES  "  "     "     "   #23
      XX(73)=36.
C     XX(19)=LAUNCHER  1 MSLS AVAILABLE OF BSAM #1
      XX(19)=4.
C     XX(20)=LAUNCHER  2  "    "       "    "  "
      XX(20)=4.
C     XX(21)=LAUNCHER  3  "    "       "    "  "
      XX(21)=4.
C     XX(22)=LAUNCHER  4 MSLS AVAILABLE OF BSAM #2
      XX(22)=4.
C     XX(23)=LAUNCHER  5  "    "       "    "  "
      XX(23)=4.
C     XX(24)=LAUNCHER  6  "    "       "    "  "
      XX(24)=4.
C     XX(51)=LAUNCHER  7 "    "    "  TSAM 12
      XX(51)=4.
C     XX(52)=LAUNCHER  8 "    "    "     "
      XX(52)=4.
C     XX(53)=LAUNCHER  9 "    "    "     "
      XX(53)=4.
C     XX(54)=LAUNCHER 10 "    "    "    TSAM 13
      XX(54)=4.
C     XX(55)=LAUNCHER 11 "    "    "       "
      XX(55)=4.
C     XX(56)=LAUNCHER 12 "    "    "       "
      XX(56)=4.
C     XX(57)=LAUNCHER 13 "    "    "    TSAM 14
      XX(57)=4.
C     XX(58)=LAUNCHER 14 "    "    "       "
      XX(58)=4.
C     XX(59)=LAUNCHER 15 "    "    "       "
      XX(59)=4.
C     XX(60)=LAUNCHER 16 "    "    "       "
      XX(60)=4.
```

```
C     XX(61)=LAUNCHER 17  "      "     "        "
      XX(61)=4.
C     XX(62)=LAUNCHER 18  "      "     "        "
      XX(62)=4.
C     XX(63)=LAUNCHER 19  "      "     "     TSAM 23
      XX(63)=4.
C     XX(64)=LAUNCHER 20  "      "     "        "
      XX(64)=4.
C     XX(65)=LAUNCHER 21  "      "     "        "
      XX(65)=4.
C     XX(66)=LAUNCHER 22  "      "     "     TSAM 22
      XX(66)=4.
C     XX(67)=LAUNCHER 23  "      "     "        "
      XX(67)=4.
C     XX(68)=LAUNCHER 24  "      "     "        "
      XX(68)=4.
C
C
C     THE FOLLOWING VARIABLE IS THE VALUE ADDED PROBABILITY
C     OF DAMAGE - ONE OF THE MOE'S OF THE MODEL.  INITIAL
C     SET TO ZERO, IT ACCUMULATES VVALUE AS TGTS ARE STRUCK
      XX(25)=0.0
C
C     XX(26)=INITIAL NUMBER OF GCI AND EW SITES AVAILABLE THIS
C        VARIABLE IS DECREASED AS ZONE 1 TARGETS ARE DESTROYED
      XX(26)=25.
C
C     THE FOLLOWING VARIABLES ARE THE REPRESENTATIVE DISTANCES
C     THE PENETRATORS FLY TO THEIR RESPECTIVE ZONES
C     XX(27)=BOMBER DISTANCE TO FLY TO ZONE 2 SRAM
      XX(27)=140
C     XX(28)=BOMBER DISTANCE TO FLY TO ZONE 3 SRAM
      XX(28)=220.
C     XX(29)=BOMBER DISTANCE TO FLY TO ZONE 4 GRAVITY
      XX(29)=300.
C     XX(30)=ALCM   DISTANCE TO FLY TO ZONE  2
      XX(30)=140.
C     XX(31)=ALCM      "     "  "  "     " 3
      XX(31)=200.
C     XX(32)=ALCM      "     "  "  "     " 4
      XX(32)=250.
C
C THE FOLLOWING TWO VARIABLES WERE DERIVED FROM DIA GREENBOOK
C FOR 1307 TARGETS
C     XX(42)=THAT PSI OVERPRESSURE TO PRODUCE A 50% PD ON TGT
C            FOR A WEAPON OF THE MEGATON CLASS
      XX(42)=8.
C     XX(43)=THAT PSI OVERPRESSURE TO PRODUCE A 50% PD ON TGT
C            FOR A WEAPON OF THE 200KT CLASS
      XX(43)=9.
```

```
      C
      C
      C     XX(44)=SAI PK DECISION RULE. IF THE S/N OR J/S RATIO
      C        AND RANGE COMBINATIONS YIELD AN ESTIMATE OF CEP
      C        WHICH WILL GIVE THE SITE A SINGLE SHOT PK GREATER THAN
      C        XX(44) THEN THE SITE WILL COMMENCE FIRING.
            XX(44)=.2
      C
            RETURN
            END
      C
      C
            FUNCTION USERF(IFN)
            COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,
           :             MSTOP,NCLNR,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,
           :             SS(100),SSL(100),TNEXT,TNOW,XX(100)
            COMMON/UCOM1/RCS(0:14,1:6),PDCIN(6),PDCOUT(6)
      C
      C     -
            GOTO(1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18),IFN
      C
      C
      C USERF(1) DETERMINES POINT OF DETECTION BY BSAM EW. IT THEN
      C DETERMINES THE TIME TO FLY TO ENVELOPE ENCOUNTER AND THE
      C TIME TO EXITTING THE BSAM COVERAGE.
      C
      C COMPUTE TIME OUT OF COVERAGE
      1     ATRIB(8)=20./ATRIB(2)*60. + TNOW
      C COMPUTE DETECTION RANGE
            X=UNFRM(0.,1.,1)
            SRNG=(540000.*X)**.257732
            IF(ATRIB(4) .GE. 499.)THEN
               SRNG=SRNG + 13.6
            ENDIF
      C DO NOT ALLOW SRNG TO BE GREATER THAN MAX ENCOUTNER RANGE
            SRNG=MIN(SRNG,20.)
      C
      C COMPUTE OFFSET DISTANCE FROM BSAM
      C OFFSET LIMIT IS BASED ON SITE DENSITY ASSUMPUTION
            YRNG=UNFRM(0.,XX(8),1)
      C  DETERMINE IF PENETRATOR COULD NOT BE DETECTED
      C  BSAM DEAD ZONE (ZONE OF NO FIRE) IS 5NM
           IF(SRNG .LE. YRNG .OR. SRNG .LE. 5.)THEN
      C        SET ATRIB(5) TO ESCAPE CONDITION
               ATRIB(5)=0.
               USERF=SRNG
               RETURN
           ELSE
               ATRIB(5) =1.
           ENDIF
```

```
            XRNG=SQRT(SRNG**2.-YRNG**2.)
            ATRIB(7)=YRNG
C           COMPUTE TIME TO SITE ENCOUTER
            ATRIB(6)=(20. - XRNG)*60./ATRIB(2)
            USERF=SRNG
            RETURN
C
C
C
C USERF(2) COMPUTES BSAM RELOAD TIMES BASED ON MISSILES
C TO BE LOADED
C XX(K) STOCKPILE OF READY MISSILES EITHER BSAM 1,2
C XX(J) LAUNCHER MISSILES REMAINING ON LAUNCHER
2           ATRIB(10)=0.
            K=ATRIB(15) + 16
            J=ATRIB(6)  + 18
C PERFORM CHECK ON STOCKPILE AND SET TIME TO RELOAD TO
C A REPRESENTATIVELY LONG TIME
            IF(XX(K) .LE. 0.01)THEN
               USERF=100.
               RETURN
            ENDIF
C
C  DETERMINE NUMBER OF MISSILES TO BE LOADED
            LOAD=4-XX(J)
            IF(XX(K) .LE. LOAD)THEN
               LOAD=XX(K)
            ENDIF
            XX(K)=XX(K) - LOAD
            XX(J)=XX(J) + LOAD
C SET TIME TO RELOAD AS A FUNCTION OF MISSILES TO BE LOADED
            USERF=1. + LOAD
            RETURN
C
C
C  USERF 3 DETERMINES CRUISE MISSILE TGT ZONE ASSIGNMENTS
C  THE FIRST 10% OF THE CM FORCE IS TARGETED IN ZONE ONE
C  AFTER THAT THE CM'S ARE CYCLICALLY ASSIGNED TO ZONES 2,3,4
C  THIS USERF IS USED FOR CORRIDOR TWO PENS AS #9 IS USED
C  FOR CORRIDOR #1
3           IF(NNCNT(4) .LE. XX(7))THEN
               USERF=1.
            ELSE
               USERF=MOD(NNCNT(4),3)+2.
            ENDIF
            RETURN
C
C  USERF(4) IS A MINI-SIMULATION OF THE BSAM ENCOUNTER
C  THE GEOMETRY STARTS AT A MAXIMUM OF 20NM OR LESS
C  DEPENDING ON DETECTION RANGE. THE SITE COMMENCES FIRING
```

```
C  WHEN THE PKSS IS AT LEAST EQUAL TO XX(44)
C
4     N=ATRIB(3)
      SRNG=ATRIB(17)
C
C     COMPUTE LAUNCHER GLOBAL VARIABLE INDEX NO.
      IF(ATRIB(14).GT.0.)THEN
         J=ATRIB(6)+44.
      ELSE
        J=ATRIB(6)+18.
      ENDIF
C   K IS THE NUMBER OF MISSILES ON LAUNCHER J
      K=XX(J)
      IF(ATRIB(1) .EQ. 2)THEN
         FACTOR=1E-21
         RL=70.0
      ELSE
         FACTOR=5.0118723E-6
         RL=135.
      ENDIF
      N=ATRIB(3)
      SRNG=ATRIB(17)
      TIME=.25
      IF(TNOW+TIME.GE.ATRIB(8))THEN
         ATRIB(5)=0.
         GOTO 60
      ENDIF
C
C      START POSITION
C
      XRNGO=(ATRIB(8)-TNOW)*ATRIB(2)/60.
C
C     POINT OF FIRST MISSILE FIRE
C
      XRNG=XRNGO - (TIME*ATRIB(2)/60.)


      SRNG=SQRT(XRNG**2+ATRIB(7)**2)
      IF(SRNG.LE.5.)THEN
         ATRIB(5)=0.
         ATRIB(8)=ATRIB(8)-1.
         GOTO 60
      ENDIF
      IXRNG=NINT(XRNG)
C
C CHECK FOR FIRING
C
      DO 30 I=IXRNG,0,-1
         AZ=ASIN(ATRIB(7)/SRNG)*57.3
         IAZ=AZ/10+.5
         SIGMAT=RCS(IAZ,N)
         IF(ATRIB(1) .EQ. 2.)THEN
```

```
C          PEN IS AN ALCM AND THE INVERSE S/N RATIO IS COMPUTED
           RATIO=FACTOR*(SRNG*1852)**4./SIGMAT
        ELSE
C          PEN IS A BOMBER AND THE J/S RATIO IS COMPUTED
           RATIO=FACTOR*(SRNG*1852)**2/SIGMAT
        ENDIF
        CEP=SQRT(2.42E-8*RATIO*(SRNG*6076)**2 + 199.*RATIO+624.)
        IF(CEP.GE.1000)THEN
           PKSS=0.0
        ELSEIF(CEP.LE.20.)THEN
           PKSS=1.0
        ELSE
           R=(RL/CEP)**2.
           PKSS=1 - .5**R
        ENDIF
        IF(PKSS .GE. XX(44))THEN
           GOTO 40
        ELSE
           XRNG=XRNG-1.
           SRNG=SQRT(XRNG**2. + ATRIB(7)**2)
           IF(XRNG .LE. 0. .OR. SRNG .LE. 5.)THEN
              ATRIB(5)=0.
           ATRIB(8)=ATRIB(8)-1.
              TIME=(XRNGO-XRNG)/ATRIB(2)*60.
              GOTO 60
           ENDIF
        ENDIF
30    CONTINUE
C
C FIRING SEQUENCE
C  FIRE UNTIL PENENTRATOR IS KILLED;LEAVES COVERAGE OR
C  K MISSILES ARE FIRED
40    DO 50 I=1,K
        IF(ATRIB(7) .LE. .01)THEN
           XRNG=2300.*SRNG/(ATRIB(2) + 2300.)
           ALPHA=1.565681
           BETA=0.0
        ELSE
           ALPHA=ATAN(XRNG/ATRIB(7))
           BETA=ASIN(COS(ALPHA)*ATRIB(2)/2300.)
           XRNG=ATRIB(7)*TAN(ALPHA-BETA)
        ENDIF
      XX(J)=XX(J)-1.
        TIME=(XRNGO-XRNG)/ATRIB(2)*60.
        SRNG=SQRT(XRNG**2. + ATRIB(7)**2.)
        AZ=(ALPHA-BETA)*57.3
        IAZ=(90. - (ALPHA - BETA)*57.3)/10 +.5
        SIGMAT=RCS(IAZ,N)
        IF(ATRIB(1) .EQ. 2)THEN
C          PEN IS AN ALCM AND THE INVERSE S/N RATIO IS COMPUTED
```

```
                 RATIO=FACTOR*(SRNG*1852)**4./SIGMAT
              ELSE
C                PEN IS A BOMBER AND THE J/S RATIO IS COMPUTED
                 RATIO=FACTOR*(SRNG*1852)**2./SIGMAT
              ENDIF
              CEP=SQRT(2.42E-8*RATIO*(SRNG*6076.)**2.+199.*RATIO+624)
              IF(CEP .GE. 1000.)THEN
                 PKSS=0.0
              ELSEIF(CEP .LE. 20.)THEN
                 PKSS=1.0
              ELSE
                 R=(RL/CEP)**2.
                 PKSS=1.-.5**R
              ENDIF
              ANGLE=BETA*57.3
              X=UNFRM(0.,.999,2)
              PK=PKSS*.8
              IF(X .LT. PK)THEN
                 ATRIB(5)=1.
                 GOTO 60
              ENDIF
C COMPUTE NEW POSITION BASED ON 3 SECOND INTERFIRE TIME
C
              DELXR=.05*ATRIB(2)/60.
              XRNG=XRNG - DELXR
              TIME=TIME + .05
              SRNG=SQRT(XRNG**2. + ATRIB(7)**2.)
              IF(XRNG .LE. 0. .OR. SRNG .LE. 5.)THEN
                 ATRIB(5)=0.
                 ATRIB(8)=ATRIB(8)-1.
                 GOTO 60
              ENDIF
50    CONTINUE
      TIME=TIME-.05
      ATRIB(5)=0.
C
C
60    USERF=TIME
      RETURN
C
C
C  USERF(5)
C    THIS USERF DETERMINES AN INDIVIDUAL MANNED PEN'S
C    TIME OF SRAM LAUNCH #1
5     USERF=(XX(27)/ATRIB(2))*60. + TNOW
      RETURN
C
C
C  USERF(6)
C    THIS USERF DETERMINES AN INDIVIDUAL MANNED PEN'S
```

```
C    TIME OF SRAM LAUNCH #2
6     USERF=(XX(28)/ATRIB(2))*60. + TNOW
      RETURN
C
C
C  USERF (7)
C    THIS USERF DETERMINES AN INDIVIDUAL MANNED PEN'S
C    TIME OF PENETRATING ZONE 4'S TERMINAL DEFENSE
C    OR IF THE PEN IS AN ALCM IT SETS THE TIME OF
C    PENETRATION OF THE ZONE IN WHICH THE ALCM IS TARGETED.
7     IF(ATRIB(1) .EQ. 1)THEN
C        THE PEN IS A BOMBER
         USERF=(XX(29)/ATRIB(2))*60. + TNOW
C     ELSE THE PEN IS AN ALCM AND
      ELSEIF(ATRIB(11) .EQ. 2.)THEN
C        HIS ZONE ASSIGNMENT IS ZONE 2
         USERF=(XX(30)/ATRIB(2))*60. + TNOW
      ELSEIF(ATRIB(11) .EQ. 3.)THEN
C        ZONE ASSIGNMENT IS ZONE 3
         USERF=(XX(31)/ATRIB(2))*60. + TNOW
      ELSE
C        ZONE ASSIGNMENT IS ZONE 4
         USERF=(XX(32)/ATRIB(2))*60. + TNOW
      ENDIF
      RETURN
C
C  USERF 8
C    THIS USERF DETERMINES THE TIME TO EW/GCI DETECTION
C   COOKIE CUTTER RADIUS OF THE SITES,XX(45)
C    THE MEAN, XMU, IS USED AS THE MEAN OF THE EXPONENTIAL TIME
C    BETWEEN ENCOUNTERS.
C
8     XMU=50000.*60./(XX(26)*XX(45)*2*ATRIB(2))
C     THE TIME TO ENCOUNTER IS:
      TTE=EXPON(XMU,3) + .33
      USERF=TTE
      RETURN
C
C
C
C USERF 9 DETERMINES CRUISE MISSILE TGT ZONE ASSIGNMENTS
C THE FIRST 10% OF THE CM FORCE IS TARGETED IN ZONE ONE
C AFTER THAT THE CM'S ARE CYCLICALLY ASSIGNED TO ZONES 2,3,4
9     IF(NNCNT(2) .LE. XX(6))THEN
         USERF=1.
      ELSE
         USERF=MOD(NNCNT(2),3)+2.
      ENDIF
      RETURN
C
```

```
C  USERF 10
C    THIS FUNCTION RETURNS USERF AS THE TIME THE FIGHTER IS
C    IS TIED UP, SETS ATRIB(5), AND ATRIB(16) IS # OF MISSILES
C    REMAINING ON THE FIGHTER.
C
C     GENERATE FTR ARRIVAL TIME
C
C     ASSUME UNIFORM ARRIVALS FROM 200 TO 400 SECS
10    FARRV=UNFRM(3.33,6.67,4) + TNOW
      IF(FARRV.GE.ATRIB(14) + 1.0)THEN
         ATRIB(5)=0.
         USERF=ATRIB(14)-TNOW
         RETURN
      ENDIF
      N=ATRIB(3)
      IF(FARRV.LE.ATRIB(19))THEN
         IF(ATRIB(1).EQ.1.)THEN
         PDC=.7*PDCIN(N)
         ELSE
         PDC=PDCIN(N)
         ENDIF
      ELSE
         IF(ATRIB(1).EQ.1.)THEN
         PDC=.7*PDCOUT(N)
         ELSE
         PDC=PDCOUT(N)
         ENDIF
      ENDIF
C
C     COMPUTE KILL/NO KILL
      X=UNFRM(0.,1.,5)
      IF(X.GT.PDC)THEN
         ATRIB(5)=0
         USERF=FARRV-TNOW
         RETURN
      ELSE
C        SINGLE SHOT PK IS ASSUMED .8 AND A TWO SHOT
C        VOLLEY YIELDS A "PKSS" OF .96
         PKSS=.96
         NVOL=ATRIB(16)
         DO 90 J=1,NVOL
            ATRIB(16)=ATRIB(16)-1.
C           ROLL THE DICE
            X=UNFRM(0.,1.,6)
            IF(X.LE.PKSS)THEN
               ATRIB(5)=1.
               USERF=FARRV-TNOW
               RETURN
            ENDIF
C
```

```
C           SECOND SHOT
            FARRV=FARRV + .2
90        CONTINUE
        ENDIF
        USERF=FARRV-TNOW
        RETURN
C
C
C  USERF 11
C    THIS FUNCTION COMPUTES THE FTR TURN AROUND TIME.
C    BASED ON A UNIFORMLY DISTRIBUTED FLYING TIME TO RTB
C    AND A CONTSTANT TURN TIME OF 40 MINUTES. NO DEGRADATION.
C
11      USERF=UNFRM(7.,17.,1) + 40.
        RETURN
C
C
C
C     USERF(12) DETERMINES THE LAUNCHER THAT THE PENETRATOR IS
C     ENGAGED BY.
C     IF CORRIDOR #1 THEN:
12    IF(ATRIB(15).EQ.1) THEN
         L=1
         M=3
      ENDIF
C      IF CORRIDOR #2 THEN:
      IF(ATRIB(15).EQ.2)THEN
         L=4
         M=6
      ENDIF
                MAX=0
                USERF=0
      DO 70 I=L,M
         IF(XX(10 + I).GT.MAX.AND.NNRSC(2+I).NE.0)THEN
         MAX=XX(10+I)
         USERF=I
         ENDIF
70    CONTINUE
      RETURN
C
C
C USERF 13
C    DETERMINES TO WHICH FTR GROUP THE PEN WILL BE SENT.  THOSE
C    FTRS WHO HAVE ONLY ONE MISSILE REMAINING ARE PRESUMED TO BE
C    SHORTEST ON FUEL AND HA\VE PRIORITY OVERPTHOS WITH A FULL
C    WEAPON COMPLEMENT.
13    IF(NNRSC(11).GT. 0)THEN
         USERF=1.
      ELSE
         USERF=2.
```

```
              ENDIF
           RETURN
      C
      C
      C  USERF 14
      C     THIS USERF RETURNS THE DELAY TIME TO RTB AND RELOAD
      C     FOR A FTR OUT OF MSLS. ALSO ZEROES ATRIB 10 OF PEN
      14    ATRIB(10)=0.
            USERF=UNFRM(7.,17.,7) + 40.
            RETURN
      C
      C
      C  USERF 15
      C     RETURNS THE FUNCTION AS TIME DELAY BEFORE A FTR CAN
      C     BE REASSIGNED TO ANOTHER PEN.  ZEROES ATRIB 10
      15    ATRIB(10)=0.
            USERF=1.
            RETURN
      C
      C     USERF 16
      C     LAUNCHER ASSIGNMENTS
      C
      C
      16    IF(ATRIB(1).EQ.1. .OR. ATRIB(11).EQ.4.)THEN
      C        SET INDICIES
               L=13
               M=18
               ATRIB(19)=71
            ELSEIF(ATRIB(15).EQ.1. .AND. ATRIB(11).EQ.2.)THEN
               L=7
               M=9
               ATRIB(19)=69
            ELSEIF(ATRIB(15).EQ.1 .AND. ATRIB(11).EQ.3)THEN
               L=10
               M=12
               ATRIB(19)=70
            ELSEIF(ATRIB(15).EQ.2 .AND. ATRIB(11).EQ.3)THEN
               L=19
               M=21
               ATRIB(19)=72
            ELSEIF(ATRIB(15).EQ.2 .AND. ATRIB(11).EQ.2)THEN
               L=22
               M=24
               ATRIB(19)=73
            ENDIF
            MAX=0
            USERF=0
            DO 400 I=L,M
               IF(XX(44+I).GT. MAX  .AND.  NNRSC(11+I).NE.0)THEN
                  MAX=XX(44+I)
```

```
               USERF=I
            ENDIF
 400     CONTINUE
         RETURN
C
C
C USERF 17
C   COMPUTES TERMINAL SAM RELOAD TIMES AND TERMINAL
C   MISSILE STOCKPILE STATUS
 17      ATRIB(10)=0.
         J=ATRIB(6)+44.
         KPILE=ATRIB(19)
C PERFORM CHECK ON STOCKPILE AND SET TIME TO A
C REPRESENTATIVELY LONG TIME IF STOCK IS OUT
         IF(XX(KPILE) .LE. 0.)THEN
            USERF=100.
            RETURN
         ENDIF
C
C DETERMINE NUMBER OF MSLS TO LOAD
         LOAD=4-XX(J)
         IF(XX(KPILE).LE.LOAD)THEN
            LOAD=XX(KPILE)
         ENDIF
         XX(KPILE)=XX(KPILE)-LOAD
         XX(J)=XX(J)+LOAD
C
C SET TIME TO RELOAD AS A FUNCTION OF MSLS TO BE LOADED
         IF(LOAD .EQ. 0.)THEN
            USERF=0.
            RETURN
         ENDIF
         USERF=1.+LOAD
         RETURN
C
C
C  USERF 18
C   RETURNS USERF AS THE TIME BETWEEN ENGAGEMENTS
C   FOR THE SAM SITE.  ALSO ZEROES ATRIB10
 18      ATRIB(10)=0.
         USERF=.2
         RETURN
         END
C
C
C
```

```
C THE FOLLOWING ARE THE EVENT SUBROUTINES IN THE MODEL
C
      SUBROUTINE EVENT(I)
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,
     :          MSTOP,NCLNR,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,
     :          SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON/UCOM2/Z1(20),Z2(60),Z3(60),Z4(60)
      GOTO(1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17),I
C
C SUBROUTINE ONE INITIALIZES XX(6) WHICH IS THE # OF CN'S
C TARGETED IN THE FIRST ZONE AND IS A FUNCTION OF THE # OF
C MANNED PENETRATORS ASSIGNED TO CORRIDOR #1,XX(1)
C IN A SIMILAR FASHION XX(7) IS SET BASED ON XX(2)
C FOR CORRIDOR #2
C
1     XX(6)=20.-XX(1)
      XX(7)=20.-XX(2)
C
C  INITIALIZE THE COOKIE CUTTER EW/GCI DETECTION RADIUS, XX(45)
C  BASED ON THE PENETRATOR'S ALTITUDE,ATRIB(4)
      IF(ATRIB(4) .LE. 201)THEN
        XX(45)=25.0
      ELSEIF(ATRIB(4) .GE. 499.)THEN
        XX(45)=39.0
      ENDIF
C  CALCULATE THE AVERAGE TIME IN COVERAGE FOR A GIVEN ENCOUNTER
C  BASED ON PEN'S ALTITUDE AND SPEED.  IN THIS CALCULATION
C  NO DIFFERENCE IS ASSUMMED BETWEEN EACH PEN'S ALT AND SPEED
      IF(XX(5) .EQ. 200.)THEN
C       CALCULATE TIC, XX(48)
        XX(48)=43.3/XX(3)*60.
      ELSEIF(XX(5) .EQ. 500.)THEN
C       CALCULATE TIC, XX(48)
        XX(48)=67.5/XX(3)*60.
      ENDIF
      RETURN
C
C
C SUBROUTINE 2 COMPUTES UPDATES THE WAPD VARIABLE,XX(25) FOR
C TARGETS STRUCK IN ZONE 1. IT ALSO DETERMINES KILL/NO KILL
C FOR THE EW/GCI SITES AND RESETS XX(26).
C
2     IF(ATRIB(1) .EQ. 2.)THEN
C     THE PENETRATOR IS A CRUISE MISSILE WITH A CEP OF 400',
C     HOB = 4000',YIELD=200KT, REP=2 * DEP.
        XREP=360*1.47
        DEP=100*1.47
C       GENERATE THE MISS DISTANCE
        X=RNORM(0.,XREP,4)
        Y=RNORM(0.,DEP,4)
```

```
              ADIS=SQRT(X**2. + Y**2.)
      C       SCALE HOB, AND MISS DISTANCE TO 1KT REFERENCE
              SHOB=4000./200.**.333333
              DIS=ADIS/200.**.333333
      C       COMPUTE ALPHA AND BETA, THE PARAMETERS FOR THE
      C       LOGNORMAL DAMAGE FUNCTION
              A=LOG(XX(43))
              B=.3
           ELSE
      C    THE PENETRATOR IS A MANNED BOMBER WITH A GRAVITY WEAPON
      C    YIELD= 1MEGATON, HOB=0.,CEP=1000., REP=2 * DEP
              XREP=900.*1.47
              DEP=450.*1.47
              X=RNORM(0.,XREP,5)
              Y=RNORM(0.,DEP,5)
      C       COMPUTE MISS DISTANCE
              ADIS=SQRT(X**2. + Y**2.)
      C       SCALE HOB AND MISS DISTANCE TO 1KT REFERENCE
              SHOB=0.
              DIS=ADIS/1000.**.333333
      C       COMPUTE ALPHA AND BETA, THE PARAMETERS FOR THE
      C       LOGNORMAL DAMAGE FUNCTION
              A=LOG(XX(42))
              B=.3
           ENDIF
      1000 SRM=SQRT(SHOB*SHOB+DIS*DIS)/3.2815
           IF(SRM .LT. 30.)THEN
              PD=1.0
              GOTO 110
           ENDIF
           IF(DIS .LT. .0001)THEN
              TT=3.1415/2
           ELSE
              TT=ATAN(SHOB/DIS)
           ENDIF
           P9=.01*EXP(40.3*SRM**(-.295))
           P0=.001*EXP(31.3*SRM**(-.2136))
           DELP=P9-(P9-P0)*COS(TT)**2.
           IF(SRM .LT. 100)GOTO 100
           W=LOG(SRM)
           A2=EXP(.35493*W**3-6.7133*W*W+41.460*W-82.819)
           B2=EXP(.25192*W**4 - 5.0741*W**3 + 50.290*W*W - 185.95*W
          :         +240.8)
           C2=EXP(.1026*W**4 - 4.36786*W**3 + 38.6017*W**2 - 149.59*W
          :    + 216.26)
           P2= COS(TT)**(2*B2)+SIN(TT)**A2*EXP(C2)
           DELP=DELP + P2
      C COMPUTE NORMALIZED "Z" VALUE
      100  Z=(LOG(DELP) - A)/B
           ZA=ABS(Z)
```

```
C CONSTANTS FOR NORMAL CURVE FIT
      T=1/(1+.2316419*ZA)
      B1=.31938153
      B2=-.356563782
      B3=1.781477937
      B4=-1.821255978
      B5=1.330274429
      FZ=EXP(-Z*Z/2)/SQRT(2*3.14159)
C     COMPUTE PD
      AREA=FZ*(B1*T + B2*T**2 + B3*T**3 + B4*T**4 + B5*T**5)
      IF(Z .LT. 0.)THEN
         PD=AREA
      ELSE
         PD=1.- AREA
      ENDIF
110   IF(LABEL .EQ. 1)GOTO 1001
      IF(LABEL .EQ. 2)GOTO 1002
      IF(LABEL .EQ. 3)GOTO 1003
      N=ATRIB(21)
      IF(N .GT. 20)THEN
         N=N-20
      ENDIF
      XX(25)=XX(25) + PD*Z1(N)/200.
      IF(PD*Z1(N) .GE. .5)THEN
         XX(26)=XX(26)-1.
      ENDIF
      Z1(N)=Z1(N) - PD*Z1(N)
      RETURN
C
C
C  SUBROUTINE 3 DESTROYS THE PENETRATOR'S CORRESPONDING
C  ENTITY ON THE ENVENT CALENDER AS THE PENETRATOR IS
C  ABOUT TO BE ENGAGED BY THE SAM SITE
3     X=ATRIB(10)
      NRANK=NFIND(1,NCLNR,10,0,X,.01)
      CALL RMOVE(NRANK,NCLNR,ATRIB)
      RETURN
C
C  SUBROUTINE 4
C   REMOVES PEN'S CORRESPONDING ENTITY FROM FILE 10 - FTR FILE
4     X=ATRIB(10)
      NRANK=NFIND(1,10,10,0,X,.01)
      CALL RMOVE(NRANK,10,ATRIB)
      RETURN
C
C SUBROUTINE 5
5     PRINT*,' SUBR 5'
      RETURN
C
C SUBROUTINE 6
```

```
6     PRINT*,'SUBR 6'
      RETURN
C
C SUBROUTINE 7
7     PRINT*,'SUBR 7'
      RETURN
C
C  SUBROUTINE 8
C    THIS SUBROUTINE DETERMINES THE AMOUNT OF TARGETS THE
C    PEN ATTACKS BASED ON WHEN HE EXITTED THE AREA.
C
C IF PEN IS AN ALCM BY PASS THIS SECTION
8      IF(ATRIB(1) .EQ. 2)GOTO 150
       IF(ATRIB(5).EQ. 0.)THEN
          ATRIB(11)=4.
          L=6
          IC=3
       ELSEIF(TNOW .GE. ATRIB(13))THEN
          ATRIB(11)=3.
          L=6
          IC=0
       ELSEIF(TNOW .GE. ATRIB(12))THEN
          ATRIB(11)=2.
          L=3
          IC=0
       ELSE
          L=0
          IC=0
       ENDIF
       ATRIB(19)=L+IC+1.
       IF(L .GT. 0)THEN
C      COMPUTE SRAM VAPD
C      SRAM CEP IS 800 FT - CIRCULAR PATTERN STEEP REENTRY ANGLE
          CEP=800.
          YIELD=200.
          HOB=4000.
          DEV=CEP*1.47
          DO 200 J=1,L
             ADIS=RNORM(0.,DEV,1)
             A=LOG(XX(43))
             B=.3
C            SCALE HOB, AND MISS DISTANCE TO 1KT REFERENCE
             SHOB=HOB/YIELD**.33333
             DIS=ADIS/YIELD**.33333
             LABEL=1
C            COMPUTE PD AND VAPD BASED ON DIS,SHOB,A,B
             GOTO 1000
1001         LABEL=0
          IF(J .LE. 3)THEN
             N=ATRIB(22)-J+1
```

```
                    IF(N.GT.60)THEN
                       N=N-60
                    ENDIF
                    XX(25)=XX(25)+PD*Z2(N)/200.
                    Z2(N)=Z2(N)-PD*Z2(N)
                 ELSE
                    N=ATRIB(23)-J+4
                    IF(N.GT.60)THEN
                       N=N-60
                    ENDIF
                    XX(25)=XX(25)+PD*Z3(N)/200.
                    Z3(N)=Z3(N)- PD*Z3(N)
                 ENDIF
      200     CONTINUE
              ENDIF
              IF(IC .GT. 0)THEN
      C          BOMB CEP IS 1000 FEET - ELLIPTICAL PATTERN
      C          XREP=2*DEP
                 YIELD=1000.
                 HOB=0.
                 XREP=900.*1.47
                 DEP=450.*1.47
                 DO 210 J=1,IC
                    X=RNORM(0.,XREP,1)
                    Y=RNORM(0.,DEP,1)
      C             COMPUTE MISS DISTANCE
                    ADIS=SQRT(X*X + Y*Y)
      C             SCALE MISS DISTANCE TO 1 KT REFERENCE
                    SHOB=0.
                    DIS=ADIS/YIELD**.333333
                    A=LOG(XX(42))
                    B=.3
                    LABEL=2
      C             COMPUTE PD AND VAPD BASED ON DIS,SHOB,A,B
                    GOTO 1000
      1002          LABEL=0
                    N=ATRIB(24)-J+1
                    IF(N .GT. 60)THEN
                       N=N-60
                    ENDIF
                    XX(25)=XX(25)+PD*Z4(N)/200.
                    Z4(N)=Z4(N) - PD*Z4(N)
      210        CONTINUE
              ENDIF
      C SUBROUTINE 8 RETURNS FOR TERMINATE COUNTS
              RETURN
      C
      C  CRUISE MISSILE SECTION
      150     YIELD=200.
              HOB=4000.
```

```
          XREP=360.*1.47
        DEP=180.*1.47
C  GENERATE THE MISS DISTANCE
        X=RNORM(0.,XREP,1)
        Y=RNORM(0.,DEP,1)
        ADIS=SQRT(X*X + Y*Y)
C  SCALE HOB, AND MISS DISTANCE TO 1KT REFERENCE
        SHOB=HOB/YIELD**.33333
        DIS=ADIS/YIELD**.33333
        A=LOG(XX(43))
        B=.3
        LABEL=3
C  COMPUTE VAPD AND PD
        GOTO 1000
1003  LABEL=0
        JJ=ATRIB(11) + 20
        N=ATRIB(JJ)
        IF(N .GT. 60)THEN
           N=N-60
        ENDIF
        IF(JJ .EQ. 22)THEN
           XX(25)=XX(25)+PD*Z2(N)/200.
           Z2(N)=Z2(N) - PD*Z2(N)
        ELSEIF(JJ .EQ. 23)THEN
           XX(25)=XX(25)+PD*Z3(N)/200.
           Z3(N)=Z3(N) - PD*Z3(N)
        ELSEIF(JJ .EQ. 24)THEN
           XX(25)=XX(25)+PD*Z4(N)/200.
           Z4(N)=Z4(N) - PD*Z4(N)
        ENDIF
C SUBR 8 RETURNS FOR TERMINATE COUNTS
        RETURN
C
C  SUBROUTINE 9
C   DETERMINES INDIVIDUAL BOMBER TGT ASSIGNMENTS WITHIN EACH ZONE
9       ATRIB(21)=NNCNT(90)+NNCNT(95)+NNCNT(91)+NNCNT(96)
        ATRIB(22)=3*(NNCNT(90)+NNCNT(95))+NNCNT(92)+NNCNT(97)
        ATRIB(23)=3*(NNCNT(90)+NNCNT(95))+NNCNT(93)+NNCNT(98)
        ATRIB(24)=3*(NNCNT(90)+NNCNT(95))+NNCNT(94)+NNCNT(99)
        RETURN
C
C
C   SUBROUTINE 10
C     DETERMINES INDIVIDUAL ALCM TGT ASSIGNMENTS WITHIN
C     ITS ASSIGNED ZONE
10      IF(ATRIB(11).EQ.1)THEN
           ATRIB(21)=NNCNT(91)+NNCNT(96)+NNCNT(90)+NNCNT(95)
        ELSEIF(ATRIB(11).EQ.2)THEN
           ATRIB(22)=NNCNT(92)+NNCNT(97)+3*(NNCNT(90)+NNCNT(95))
        ELSEIF(ATRIB(11).EQ.3)THEN
```

```
        ATRIB(23)=NNCNT(93)+NNCNT(94)+3*(NNCNT(90)+NNCNT(95))
      ELSEIF(ATRIB(11).EQ.4)THEN
        ATRIB(24)=NNCNT(94)+NNCNT(99)+3*(NNCNT(90)+NNCNT(95))
      ENDIF
      RETURN
C
C
C
C
C SUBROUTINE 11 ILLIMINATES THE PENETRATOR'S CORRESPONDING
C ENTITY FROM SAM AWAIT FILE #1.
11    X=ATRIB(10)
      NRANK=NFIND(1,1,10,0,X,.01)
      CALL RMOVE(NRANK,1,ATRIB)
      RETURN
C
C  SUBROUTINE 12 ILLIMINATES THE PENETRATOR'S CORRESPONDING
C  ENTITY FROM SAM AWAIT FILE #2.
12    X=ATRIB(10)
      NRANK=NFIND(1,2,10,0,X,.01)
      CALL RMOVE(NRANK,2,ATRIB)
      RETURN
C
C
C
C  SUBROUTINE 13 ELIMINATES THE PENETRATOR'S CORRESPONDING
C                 ENTITY FROM TERM SAM AWAIT FILE CORRIDOR "1 Z2'
13    X=ATRIB(10)
      NRANK=NFIND(1,13,10,0,X,.01)
      CALL RMOVE(NRANK,13,ATRIB)
      RETURN
C
C
C  SUBROUTINE 14 ELIMINATES THE PENETRATOR'S CORRESPONDING
C                ENTITY FROM TSAM AWAIT FILE-CORRIDOR# 1 ZONE 3
14    X=ATRIB(10)
      NRANK=NFIND(1,14,10,0,X,.01)
      CALL RMOVE(NRANK,14,ATRIB)
      RETURN
C
C
C  SUBROUTINE 15
C     ELIMINATES THE PENETRATOR'S CORRESPONDING ENTITY FROM
C     TSAM AWAIT FILE 15 - ZONE4
15    X=ATRIB(10)
      NRANK=NFIND(1,15,10,0,X,.01)
      CALL RMOVE(NRANK,15,ATRIB)
      RETURN
C
C
```

```
C   SUBROUTINE 16
C      ELIMINATES THE PENETRATOR'S CORRESPONDING ENTITY FROM
C      TSAM AWAIT FILE 16 - CORRIDOR#2,ZONE 3
16    X=ATRIB(10)
      NRANK=NFIND(1,16,10,0,X,.01)
      CALL RMOVE(NRANK,16,ATRIB)
      RETURN
C     ------
C
C   SUBROUTINE 17
C      ELIMINATES THE PENETRATOR'S CORRESPONDING ENTITY
C      FROM TSAM AWAIT FILE 17 - CORRIDOR#2, ZONE 2
17    X=ATRIB(10)
      NRANK=NFIND(1,17,10,0,X,.01)
      CALL RMOVE(NRANK,17,ATRIB)
      RETURN
      END
C
C
C
C
C OUTPUT SUBROUTINE
      SUBROUTINE OTPUT
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,
     :              MSTOP,NCLNR,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,
     :              SS(100),SSL(100),TNEXT,TNOW,XX(100)
      DIMENSION AVE(60)
      IF(NNRUN.GE.1)THEN
         DO 3000 I=1,60
            AVE(I)=0.
3000     CONTINUE
         TRUNS=100.
      ENDIF
      PRINT*
      PRINT*
      PRINT*
      PRINT*,'FOR RUN NUMBER ',NNRUN
      PRINT*,
      NB=XX(1)+XX(2)
      NM=XX(11)+XX(12)
      NPENS=NB+NM
      NBSBS1=XX(1)-NNCNT(7)
      NMSBS1=XX(11)-NNCNT(8)
      NSBS1=NBSBS1+NMSBS1
      NBSBS2=XX(2)-NNCNT(25)
      NMSBS2=XX(12)-NNCNT(26)
      NSBS2=NBSBS2+NMSBS2
      NNBBS=NNCNT(78)+NNCNT(79)
      NESCBS=NNCNT(9)+NNCNT(20)
      PESCBS=FLOAT(NESCBS)/(NPENS-NNBBS)
```

```
      NBSBS=NBSBS1+NBSBS2
      NMSBS=NMSBS1+NMSBS2
      NSBS=NBSBS+NMSBS
      IF(NB.GT.0)THEN
         PSBBS=FLOAT(NBSBS)/NB
      ELSE
         PSBBS=9999
      ENDIF
      IF(NM.GT.0)THEN
         PSMBS=FLOAT(NMSBS)/NM
      ELSE
         PSMBS=9999
      ENDIF
      PSBS=FLOAT(NSBS)/NPENS
      NBAI=NNCNT(16)
      NMAI=NNCNT(14)
      NAI=NBAI+NMAI
      IF(NAI .GT. 0)THEN
         ENCPER=(NNCNT(33)-NNCNT(28))/FLOAT(NAI)
      ELSE
         ENCPER=9999.
      ENDIF
      NBSAI=NBAI-NNCNT(34)
      NMSAI=NMAI-NNCNT(35)
      NSAI=NBSAI+NMSAI
      IF(NNCNT(29)+NNCNT(76) .GT. 0)THEN
         PDCK=FLOAT(NNCNT(29))/(NNCNT(29)+NNCNT(76))
      ELSE
         PDCK=9999.
      ENDIF
      IF(NBAI.GT.0)THEN
         PSBAI=FLOAT(NBSAI)/NBAI
      ELSE
         PSBAI=9999
      ENDIF
C
      IF(NMAI.GT.0)THEN
         PSMAI=FLOAT(NMSAI)/NMAI
      ELSE
         PSMAI=9999
      ENDIF
C
      IF(NAI.GT.0)THEN
         PSAI=FLOAT(NSAI)/NAI
      ELSE
         PSAI=9999
      ENDIF
      AVE(1)=AVE(1)+NBSBS1/TRUNS
      AVE(2)=AVE(2)+NMSBS1/TRUNS
      AVE(3)=AVE(3)+NSBS1/TRUNS
```

```
      AVE(4)=AVE(4)+NBSBS2/TRUNS
      AVE(5)=AVE(5)+NMSBS2/TRUNS
      AVE(6)=AVE(6)+NSBS2/TRUNS
      AVE(7)=AVE(7)+NMDBS/TRUNS
      AVE(8)=AVE(8)+NESCBS/TRUNS
      AVE(9)=AVE(9)+PESCBS/TRUNS
      AVE(10)=AVE(10)+NBSBS/TRUNS
      AVE(11)=AVE(11)+NMSBS/TRUNS
      AVE(12)=AVE(12)+NSBS/TRUNS
      AVE(13)=AVE(13)+PSBBS/TRUNS
      AVE(14)=AVE(14)+PSMBS/TRUNS
      AVE(15)=AVE(15)+PSBS/TRUNS
      AVE(16)=AVE(16)+NBAI/TRUNS
      AVE(17)=AVE(17)+NMAI/TRUNS
      AVE(18)=AVE(18)+NAI/TRUNS
      AVE(19)=AVE(19)+ENCPER/TRUNS
      AVE(20)=AVE(20)+NBSAI/TRUNS
      AVE(21)=AVE(21)+NMSAI/TRUNS
      AVE(22)=AVE(22)+NSAI/TRUNS
      AVE(23)=AVE(23)+PDCK/TRUNS
      AVE(24)=AVE(24)+PSBAI/TRUNS
      AVE(25)=AVE(25)+PSMAI/TRUNS
      AVE(26)=AVE(26)+PSAI/TRUNS
C
C
C
C
      NTS12=NNCNT(37)
      NSTS12=NTS12-NNCNT(49)
      NTS13=NNCNT(38)
      NSTS13=NTS13-NNCNT(54)
      NTS14=NNCNT(39)
      NSTS14=NTS14-NNCNT(59)-NNCNT(60)
      NTS23=NNCNT(40)
      NSTS23=NTS23-NNCNT(68)
      NTS22=NNCNT(41)
      NSTS22=NTS22-NNCNT(73)
      NNBETS=NNCNT(77)
      NESCTS=NNCNT(42)+NNCNT(43)+NNCNT(44)+NNCNT(45)+NNCNT(46)
      NBSTS=NBSAI-NNCNT(59)
      NMSTS=NMSAI-NNCNT(49)-NNCNT(54)-NNCNT(60)-NNCNT(68)-NNCNT(73)
      NSTS=NBSTS+NMSTS
C
      TENTS=NTS12+NTS13+NTS14+NTS23+NTS22
         IF(TENTS.LE.0.)THEN
         PESCTS=9999
      ELSE
         PESCTS=NESCTS/TENTS
      ENDIF
      IF(NBSAI.GT.0)THEN
```

```
               PSBTS=FLOAT(NBSTS)/NBSAI
            ELSE
               PSBTS=9999
            ENDIF
C
            IF(NMSAI.GT.0)THEN
               PSMTS=FLOAT(NMSTS)/NMSAI
            ELSE
               PSMTS=9999
            ENDIF
C
            IF(NSAI.GT.0)THEN
               PSTS=FLOAT(NSTS)/NSAI
            ELSE
               PSTS=9999
            ENDIF
C
            AVE(27)=AVE(27)+NTS12/TRUNS
            AVE(28)=AVE(28)+NSTS12/TRUNS
            AVE(29)=AVE(29)+NTS13/TRUNS
            AVE(30)=AVE(30)+NSTS13/TRUNS
            AVE(31)=AVE(31)+NTS14/TRUNS
            AVE(32)=AVE(32)+NSTS14/TRUNS
            AVE(33)=AVE(33)+NTS23/TRUNS
            AVE(34)=AVE(34)+NSTS23/TRUNS
            AVE(35)=AVE(35)+NTS22/TRUNS
            AVE(36)=AVE(36)+NSTS22/TRUNS
            AVE(37)=AVE(37)+NNDETS/TRUNS
            AVE(38)=AVE(38)+NESCTS/TRUNS
            AVE(39)=AVE(39)+NBSTS/TRUNS
            AVE(40)=AVE(40)+NMSTS/TRUNS
            AVE(41)=AVE(41)+NSTS/TRUNS
            AVE(42)=AVE(42)+PSBTS/TRUNS
            AVE(43)=AVE(43)+PSMTS/TRUNS
            AVE(44)=AVE(44)+PSTS/TRUNS
C
C
            BWPNS=10*(XX(1)+XX(2))
               IF(BWPNS.GT.0.)THEN
                  BWE=(NNCNT(81)+4*NNCNT(82)+7*NNCNT(83)+10*NNCNT(84))/BWPNS
               ELSE
                  BWE=9999
               ENDIF
               IF(NN.GT.0)THEN
                  CNWE=(NNCNT(15)+NNCNT(85))/FLOAT(NN)
               ELSE
                  CNWE=9999
               ENDIF
            NWPN1=NNCNT(13)
            NWPN2=NSTS12+NSTS22+3*NNCNT(82)+3*NNCNT(83)+3*NNCNT(84)
```

```
      NWPN3=NSTS13+NSTS23+3*NNCNT(83)+3*NNCNT(84)
      NWPN4=NSTS14-NNCNT(84)+3*NNCNT(84)
      NWPNS=NWPN1+NWPN2+NWPN3+NWPN4
      VAPD=XX(25)
      AVE(53)=AVE(53)+VAPD**2
         IF(NB.GT.0)THEN
            PSB=FLOAT(NNCNT(84))/NB
            AVE(55)=AVE(55)+PSB**2
         ELSE
            PSB=9999
            AVE(55)=9999
         ENDIF
         IF(NM.GT.0)THEN
            PSA=(NNCNT(85)+NNCNT(15))/FLOAT(NM)
            AVE(57)=AVE(57)+PSA**2
         ELSE
            PSA=9999
            AVE(57)=9999
         ENDIF
      PSFL=(NNCNT(84)+NNCNT(85)+NNCNT(15))/FLOAT(NPENS)
      AVE(45)=AVE(45)+BME/TRUNS
      AVE(46)=AVE(46)+CHME/TRUNS
      AVE(47)=AVE(47)+NWPN1/TRUNS
      AVE(48)=AVE(48)+NWPN2/TRUNS
      AVE(49)=AVE(49)+NWPN3/TRUNS
      AVE(50)=AVE(50)+NWPN4/TRUNS
      AVE(51)=AVE(51)+NWPNS/TRUNS
      AVE(52)=AVE(52)+VAPD/TRUNS
      AVE(54)=AVE(54)+PSB/TRUNS
      AVE(56)=AVE(56)+PSA/TRUNS
      AVE(58)=AVE(58)+PSFL/TRUNS
      AVE(59)=AVE(59)+PSFL**2
C SET UP INDEPENDENT VARIABLE INDICIES
      IF(NB .EQ. 0)THEN
         IFN=5
      ELSEIF(NB .EQ. 8)THEN
         IFN=4
      ELSEIF(NB .EQ. 20)THEN
         IFN=3
      ELSEIF(NB .EQ. 32)THEN
         IFN=2
      ELSEIF(NB .EQ. 40)THEN
         IFN=1
      ENDIF
      IF(XX(3) .EQ. 300.)THEN
         ISPEED=1
      ELSEIF(XX(3) .EQ. 600.)THEN
         ISPEED=2
      ELSEIF(XX(3) .EQ. 800.)THEN
         ISPEED=3
```

```
            ENDIF
            PRINT*,' RCS SET ',XX(4),'  SPEED SET ',ISPEED,'  KNOTS ',XX(3)
            IRCS=XX(4)
C
C
            PRINT*
            CALL HEADER1
C
C
            PRINT 2300,NB,NBSBS1,NBSBS2,NBSBS,PSBBS,NBAI,
           :NBSAI,PSBAI,NM,NMSBS1,NMSBS2,NMSBS,PSMBS,NMAI,
           :NMSAI,PSMAI,NPENS,NSBS1,NSBS2,NMDBS,NESCBS,PESCBS,
           :NSBS,PSBS,NAI,ENCPER,NSAI,PDCX,PSAI
      2300  FORMAT(2(T2,I3,T10,I3,T19,I3,T52,I3,T59,F5.3,T69,I3,
           :T90,I3,T110,F5.3/),T2,I3,T10,I3,T19,I3,T29,I3,
           :T38,I3,T43,F5.3,T52,I3,T59,F5.3,T69,I3,T77,F5.2,
           :T90,I3,T100,F5.3,T110,F5.3/)
C
C
            CALL HEADER2
C
C
            PRINT 2400,NBSTS,PSBTS,NMSTS,PSMTS,NTS12,NSTS12,
           :NTS13,NSTS13,NTS14,NSTS14,NTS23,NSTS23,
           :NTS22,NSTS22,NMDETS,NESCTS,NSTS,PSTS
      2400  FORMAT(2(T109,I3,T115,F5.3/),T4,I3,T12,I3,
           :T22,I3,T30,I3,T39,I3,T47,I3,T56,I3,T64,I3,
           :T74,I3,T82,I3,T92,I3,T101,I3,T109,I3,T115,F5.3/)
C
C
            CALL HEADER3
C
C
            PRINT 2500,BME,CMME,VAPD,PSB,PSA,PSFL,NMPN1,NMPN2,
           :NMPN3,NMPN4,NMPNS
      2500  FORMAT(T2,F5.3,T12,F5.3,T21,F7.5,T29,F5.3,T35,
           :F4.3,T40,F5.4,T47,I2,T53,I2,T59,I2,T65,I2,T72,I3)
C
            WRITE(69,*)IFN,ISPEED,IRCS,VAPD,PSBBS,PSMBS,PSBAI,PSMAI
           :,PSBTS,PSMTS,PSA,PSB,PSFL,PESCBS,PESCTS
            PRINT*
            PRINT*,' WROTE DATA SET# ',NNRUN,' TO TAPE 69'
            PRINT*
C     THIS SECTION COMPUTES THE STANDARD DEVIATIONS
C
            IF(NNRUN.GT.TRUNS)THEN
               SDVAPD=SQRT((AVE(53)-TRUNS*AVE(52))/(TRUNS-1))
               SDPSB=SQRT((AVE(55)-TRUNS*AVE(54))/(TRUNS-1))
               SDPSA=SQRT((AVE(57)-TRUNS*AVE(58))/(TRUNS-1))
               SDPSFL=SQRT((AVE(59)-TRUNS*AVE(58))/(TRUNS-1))
```

```
      PRINT*,
        PRINT '(30("X"))'
        PRINT*
        PRINT*, ' FINAL RESULTS - RUN PARAMETERS:'
        IF(XX(1).EQ.0.)THEN
          IFM=5
        ELSEIF(XX(1).EQ.2)THEN
          IFM=4
        ELSEIF(XX(1).EQ.5)THEN
          IFM=3
        ELSEIF(XX(1).EQ.8)THEN
          IFM=2
        ELSEIF(XX(1).EQ.10)THEN
          IFM=1
        ENDIF
      PRINT*,'FORCE MIX# ',IFM
        PRINT*,'RCS SET: ',XX(4)
        PRINT*,'SPEED : ',XX(3),' KNOTS'
        PRINT*,' ALTITUDE : ',XX(2),' FEET'
        PRINT*,' SITE DENSITY : ',2*XX(8),' SITES/NM'
        PRINT*
C
      CALL HEADER1
      PRINT 2600,NB,AVE(1),AVE(4),AVE(10),AVE(13),AVE(16),
     :AVE(20),AVE(24),NM,AVE(2),AVE(5),AVE(11),AVE(14),
     :AVE(17),AVE(21),AVE(25),NPENS,AVE(3),AVE(6),AVE(7),
     :AVE(8),AVE(9),AVE(12),AVE(15),AVE(18),AVE(19),
     :AVE(22),AVE(23),AVE(26)
 2600 FORMAT(2(T2,I3,T9,F7.3,T18,F7.3,T51,F7.3,T59,F5.3,
     :T67,F7.3,T89,F7.3,T110,F6.4/),T2,I3,T9,F7.3,T18,
     :F7.3,T28,F7.4,T37,F7.3,T43,F5.3,T51,F7.3,T59,F5.3,
     :T67,F7.3,T76,F6.3,T89,F7.3,T100,F6.4,T110,F6.4/)
C
C
      CALL HEADER2
      PRINT 2700,AVE(39),AVE(42),AVE(40),AVE(43),AVE(27),
     :AVE(28),AVE(29),AVE(30),AVE(31),AVE(32),AVE(33),
     :AVE(34),AVE(35),AVE(36),AVE(37),AVE(38),AVE(41),
     :AVE(44)
 2700 FORMAT(2(T109,F6.2,T115,F5.4/),T2,F7.3,T11,F7.3,T20,
     :F7.3,T29,F7.3,T37,F7.3,T46,F7.3,T54,F7.3,T63,F7.3,
     :T72,F7.3,T81,F7.3,T90,F7.3,T100,F7.3,T109,F6.2,
     :T115,F5.4/)
C
C
      CALL HEADER3
        PRINT 2800,AVE(45),AVE(46),AVE(52),AVE(54),AVE(56),
     :  AVE(53),AVE(47),AVE(48),AVE(49),AVE(50),AVE(51)
 2800 FORMAT(T2,F6.4,T12,F6.4,T22,F6.5,T28,F5.3,T34,F5.3,
     :  T39,F6.4,T46,F5.2,T52,F5.2,T58,F5.2,
```

```
                :   T64,F5.2,T71,F7.3/)
C
C
C     RESET FOR NEXT RUN
C
C
            DO 2900 I=1,60
              AVE(I)=0.
2900        CONTINUE
          ENDIF
      RETURN
      END
C
C
      SUBROUTINE HEADER1
      PRINT 2000,'BANDSAM SURVIVORS','*',
     :'TOTAL CORRIDOR CORRIDOR  NOT','PROB','TOT BSAM',
     :'BSAM *','ENTERING','EXP0','TOTAL AI',
     :'AI PDC&K/','PENS','#1','#2','DETECTED',
     :'ESCAPED','ESC','SURVIVORS','PS  *','AI AREA',
     :'ENCOUNTERS','SURVIVORS','ENCOUNTER','PSAI'
2000  FORMAT(/T8,A,T65,A/T2,A,T44,A,T50,A,
     :T60,A,T67,A,T77,A,T87,A,T98,A/T2,A,T11,A,
     :T19,A,T27,A,T36,A,T44,A,T50,A,T61,A,T67,A,
     :T76,A,T87,A,T98,A,T110,A)
      RETURN
      END
C
C
      SUBROUTINE HEADER2
      PRINT 2100,'TSAM12','TSAM13','TSAM14','TSAM23','TSAM22',
     :'NOT','TOTL','TSAM','ENTERED/SURVIVED',
     :'ENTERED/SURVIVED','ENTERED/SURVIVED','ENTERED/SURVIVED',
     :'ENTERED/SURVIVED','DETECTED','ESCAPED','SURV','PS'
2100  FORMAT(/T7,A,T25,A,T42,A,T59,A,T77,A,T92,A,
     :T110,A,T116,A/T2,A,T20,A,T37,A,T54,A,T72,A,
     :T90,A,T100,A,T110,A,T117,A)
      RETURN
      END
C
C
      SUBROUTINE HEADER3
      PRINT 2200,'MISSION EFFECTIVENESS','WEAPONS  DELIVERED',
     :'TOTAL',
     :'BOMBER','ALCM','VAPO','PSB','PSA','PSFL',
     :'ZONE1 ZONE2 ZONE3 ZONE4','WPNS'
2200  FORMAT(/T2,A,T40,A,T71,A/T3,A,T13,A,T24,A,T30,A,T35,A,
     :T40,A,T46,A,T71,A)
      RETURN
      END
```

APPENDIX D

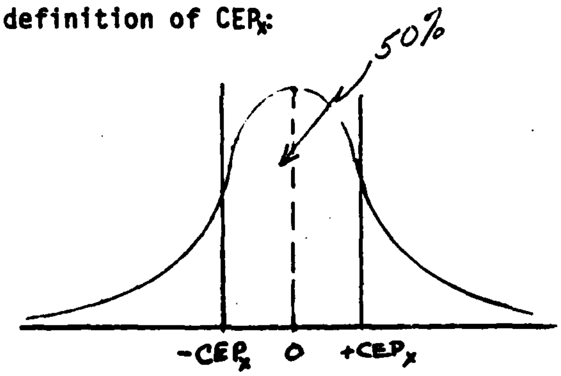
DERIVATION OF WEAPON SIGMAS

Appendix D

Weapon miss distances are normally described in terms of a singular CEP (Circular Error Probable). CEP is the median miss distance of a weapon. This does not say anything about the distribution of those miss distances, only that 50% lie below and 50% above the CEP.

In the model DILUTE hit patterns were modeled by normal distributions with a mean of zero and standard deviation functionally related to CEP. The following analysis equates CEP_x with the standard deviation from a normal distribution for a single variate case and then extend the analysis to the bivariate case.

From the definition of CEP_x:



where + and - denotes direction.

Assuming a normal probability density function:

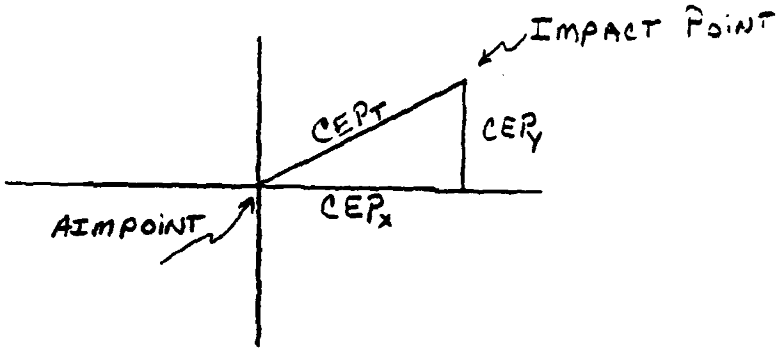
$$\int_{-\infty}^{+CEP_x} \frac{1}{\sqrt{2\pi}\,\sigma_x} e^{-x/2\sigma_x}\,dx = .75 \qquad (40)$$

solving for σ_x:

$$CEP_x/\sigma_x = .68$$

$$\sigma_x = 1.47 * CEP_x \qquad (41)$$

For the bivariate case:



where:

$$CEP_T = \sqrt{CEP_x^2 + CEP_y^2} \tag{42}$$

To solve for σ_x and σ_y first state one CEP as a multiple of the other:

$$CEP_x = N * CEP_y \tag{43}$$

Substituting into equation (42):

$$CEP_T = \sqrt{(CEP_x)^2 + (CEP_x/N)^2}$$

$$CEP_T = \frac{\sqrt{N^2 + 1}}{N} * CEP_x$$

$$CEP_x = \frac{N}{\sqrt{N^2 + 1}} * CEP_T \tag{44}$$

Substituting into equation (43):

$$CEP_y = CEP_T / \sqrt{N^2 + 1} \tag{45}$$

Once the CEP is broken out then the standard deviation for each direction may be calculated via equation (41).

For ALCM and bomber gravity weapons N = 2, and for SRAM N = 1. The following are the CEPs used for each weapon:

	Gravity	ALCM	SRAM
CEP_T	1000	400	800
CEP_x	900	360	570
CEP_y	450	180	570

APPENDIX E

CURVE FIT FOR OVERPRESSURE "KNEE" CURVES

Appendix E

This Appendix includes the curve fits for the overpressure "knee" curves and the normal distribution used for computing probability of damage.

Overpressure Curve

The curve fit used was taken from (Ref 25)

Let: SRM = scaled Slant Range in meters

SHOB = scaled heights of burst in feet

DIS = scaled Ground Range in feet

DELP = Overpressure

```
      IF(DIS .LT. .0001)THEN
        TT=3.1415/2
      ELSE
        TT=ATAN(SHOB/DIS)
      ENDIF
      P9=.01*EXP(40.3*SRM**(-.295))
      P0=.001*EXP(31.3*SRM**(-.2136))
      DELP=P9-(P9-P0)*COS(TT)**2.
      IF(SRM .LT. 100)GOTO 100
      W=LOG(SRM)
      A2=EXP(.35493*W**3-6.7133*W*W+41.468*W-82.819)
      B2=EXP(.25192*W**4 - 5.8741*W**3 + 50.298*W*W - 185.95*W
     :          +248.8)
      C2=EXP(.1826*W**4 - 4.36786*W**3 + 38.6017*W**2 - 149.59*W
     :     + 216.26)
      P2= COS(TT)**(2*B2)*SIN(TT)**A2*EXP(C2)
      DELP=DELP + P2
```

PD Calculation

Once the overpressure, DELP, is calculated the Probability of Damage (PD) is computed. PD is assumed to follow a log normal distribution with parameters α and β. If PD(Δ p) follows a lognormal curve, then PD(ln(Δp)) follows a normal curve.

The following transformation was used to obtain a normally distributed random variable with a mean of zero and standard deviation of one:

$$z = \frac{\ln(\mathrm{DELP}) - \alpha}{\beta} \qquad (46)$$

The probability density function for the standard normal curve:

$$f(z) = \frac{1}{\sqrt{2\pi}} \; e^{-\frac{1}{2}z^2} \qquad (47)$$

The following curve fit was used to approximate the area under the normal density function. The curve fit is valid for positive values of z (Ref 35:49):

```
C CONSTANTS FOR NORMAL CURVE FIT
      T=1/(1+.2316419*ZA)
      B1=.31938153
      B2=-.356563782
      B3=1.781477937
      B4=-1.821255978
      B5=1.330274429
      FZ=EXP(-Z*Z/2)/SQRT(2*3.14159)
C     COMPUTE PD
      AREA=FZ*(B1*T + B2*T**2 + B3*T**3 + B4*T**4 + B5*T**5)
      IF(Z .LT. 0.)THEN
         PD=AREA
      ELSE
         PD=1.- AREA
      ENDIF
```

APPENDIX F

DESCRIPTION OF SLAM ATTRIBUTE VALUES

The array ATRIB(I) contains the values of the attributes assigned for each entity. This appendix contains a description of the attributes assigned to the penetrators. Where more than one description is given the role of the attribute changed as the entity traveled through the network. This was done in order to conserve computer core memory.

ATRIB(1) = Type of penetrator (1=Bomber, 2=ALCM)

ATRIB(2) = Speed of penetrator

ATRIB(3) = RCS level

ATRIB(4) = Altitude

ATRIB(5) =
- Detect =1/ No detect=0
- Kill =1/ No Kill =0

ATRIB(6) =
- Time to enter the first point of possible SAM encounter
- Index to determine the launcher assignments for the SAM

ATRIB(7) = Distance offset from SAM site

ATRIB(8) = The time that the penetrator exits the SAM coverage

ATRIB(9) = Time of next GCI detection

ATRIB(10)= Sequence number of the penetrator

ATRIB(11)= Zone to which penetrator is targeted (ALCM)

ATRIB(12)= Bomber time of SRAM launch in Zone 2

ATRIB(13)= Bomber time of SRAM launch in Zone 3

ATRIB(14)=
- Time of Bomber penetration into Zone 4
- Time of ALCM penetration into Zones 2, 3, or 4

ATRIB(15)= Corridor number of penetration

ATRIB(16)= Number of missiles the fignter has left after an engagement

ATRIB(17)= Slant range of SAM encounter

ATRIB(18)= Enroute time to the next AI encounter

ATRIB(19)=
- Time of exiting the current GCI radar coverage
- Total number of weapons released by the entity

ATRIB(20)= not used

ATRIB(21)= Entity's target assignment within Zone 1

ATRIB(22)= Entity's target assignment within Zone 2

ATRIB(23)= Entity's target assignment within Zone 3

ATRIB(24)= Entity's target assignment within Zone 4

APPENDIX G

SIMULATION RUN OUTPUT

This appendix contains the output from a single run of the model DILUTE. Force Mix 3 (200 ALCM/ 20 Bombers) was used. RCS and Speed were set at level 2. The key variables used in data analysis were PROB ESC (Probability of Escape - that is the probability that a penetrator will egress the SAM coverage while the site is either tied up with other penetrators or has exhausted its supply of missiles), BSAM PS (Band SAM Probability of Survival), PSAI (Probability of Survival of the AI threat), TSAM PS (Terminal SAM Probability of Survival), VAPD (Value Average Probability of Damage), and PSB (Probability of Survival of the Bomber). Where there are three rows under a heading the first row pertains to Bombers, the second row pertains to ALCMs, and the third row shows the total for both ALCM and Bomber.

FOR RUN NUMBER 1

RCS SET 2. SPEED SET 2 KNOTS 600.

TOTAL PENS	BANDSAM SURVIVORS CORRIDOR #1	CORRIDOR #2	NOT DETECTED	ESCAPED	PROB ESC	TOT BSAM SURVIVORS	BSAM PS	# ENTERING AI AREA	EXP# ENCOUNTERS	TOTAL AI SURVIVORS	AI PBC&K/ ENCOUNTER	PSAI
20	8	9				17	.850	17		9		.529
200	65	66				131	.655	124		94		.758
220	73	75	3	82	.378	148	.673	141	1.11	103	.244	.730

TSAM12 ENTERED/	SURVIVED	TSAM13 ENTERED/	SURVIVED	TSAM14 ENTERED/	SURVIVED	TSAM23 ENTERED/	SURVIVED	TSAM22 ENTERED/	SURVIVED	NOT DETECTED	ESCAPED	TOTL SURV	TS PS
												2	.222
												2	.021
17	0	15	1	35	2	17	0	19	1	0	0	4	.039

MISSION EFFECTIVENESS BOMBER	ALCM	VAPD	PSB	PSA	PSFL	WEAPONS DELIVERED ZONE1	ZONE2	ZONE3	ZONE4	TOTAL WPNS
.475	.045	.46400	.100	.045	.0500	24	37	37	6	104

WROTE DATA SETS 1 TO TAPE 69

..

APPENDIX H

The first two pages of this Appendix contains a sample of the SPSS program used to analyze the data obtained from DILUTE. The remaining pages contain the output of the ANOVA experiments discussed in Chapter V.

```
THE INPUT FORMAT PROVIDES FOR 15 VARIABLES.   15 WILL BE READ.
IT PROVIDES FOR  1 RECORDS (*CARDS*) PER CASE.
A MAXIMUM OF   121 *COLUMNS* ARE USED ON A RECORD.

                   MISSING VALUES ALL(9)
                   VAR LABELS     IFM,FORCE MIX/
                                  ISPEED,SPEED/
                                  IRCS,RCS IN DB DOWN FROM REFERENCE/
                                  VAPD,VALUE AVERAGE PROBABILITY OF DAMAGE*
                                  PSBBS,PROB OF SURV OF BOMBERS AT BAND SA*
                                  PSMBS,PROB SURV OF ALCMS AT BAND SAM/
                                  PSBAI,PROB SURV OF BOMBERS IN AI AREA/
                                  PSMAI,PROB SURV OF ALCMS IN AI AREA/
                                  PSBTS,PROB SURV OF BOMBERS AT TERMINAL S*
                                  PSMTS,PROB SURV OF ALCMS AT TERMINAL SAM*
                                  PSA,PROB SURV OF ALCM FORCE/
                                  PSB,PROB SURV OF BOMBER FORCE/
                                  PSFL,PROB SURV OF FLEET/
                                  PESCBS,PROB ESCAPING BAND SAM/
                                  PESCTS,PROB ESCAPING TERM SAM/

                   VALUE LABELS   IFM (1)  0 ALCM   40 BOMBERS
                                  IFM (2) 80 ALCM   32 BOMBERS
                                  IFM (3)200 ALCM   20 BOMBERS
                                  IFM (4)320 ALCM    8 BOMBERS
                                  IFM (5)400 ALCM    0 BOMBERS/
                                  ISPEED (1)300 KNOTS (2)600 KNOTS (3)900 *
                                  IRCS (1) 0 DB (2) -10 DB (3) -20 DB
                   PRINT FORMATS  VAPD TO PESCTS (4)
                   ANOVA          PSBBS BY IFM(1,5),ISPEED(1,3),IRCS(1,3)/
                                  PSMBS BY IFM(1,5),ISPEED(1,3),IRCS(1,3)/
                   STATISTICS     ALL

              00057100 CM NEEDED FOR ANOVA
```

```
VOGELBACK COMPUTING CENTER
NORTHWESTERERN UNIVERSITY

S P S S - - STATISTICAL PACKAGE FOR THE SOCIAL SCIENCES

VERSION 8.0 -- JUNE 16, 1979




        RUN NAME        DILUTE
        VARIABLE LIST   IFM,ISPEED,IRCS,VAPD,PSBBS,PSMBS,PSBAI,P=
                        PSBTS,PSMTS,PSA,PSB,PSFL,PESCBS,PESCTS
        INPUT MEDIUM    TAPE
        N OF CASES      450
        INPUT FORMAT    FIXED(T2,F2.0,2X,F2.0,2X,F2.0,2X,12F9.5)


        ACCORDING TO YOUR INPUT FORMAT, VARIABLES ARE TO BE READ=

        VARIABLE  FORMAT  RECORD    COLUMNS

        IFM       F 2. 0       1      2-   3
        ISPEED    F 2. 0       1      6-   7
        IRCS      F 2. 0       1     10-  11
        VAPD      F 9. 5       1     14-  22
        PSBBS     F 9. 5       1     23-  31
        PSMBS     F 9. 5       1     32-  40
        PSBAI     F 9. 5       1     41-  49
        PSMAI     F 9. 5       1     50-  58
        PSBTS     F 9. 5       1     59-  67
        PSMTS     F 9. 5       1     68-  76
        PSA       F 9. 5       1     77-  85
        PSB       F 9. 5       1     86-  94
        PSFL      F 9. 5       1     95- 103
        PESCBS    F 9. 5       1    104- 112
        PESCTS    F 9. 5       1    113- 121
```

* * * * * * * * * A N A L Y S I S   O F   V A R I A N C E * * * * * * * * *

VAPD — VALUE AVERAGE PROBABILITY OF DAMAGE
BY IFM — FORCE MIX
ISPEED — SPEED
IRCS — RCS IN DB DOWN FROM REFERENCE

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	12.668	8	1.584	400.386	.001
IFM	.869	4	.217	54.955	.001
ISPEED	1.636	2	.818	206.825	.001
IRCS	10.163	2	5.081	1284.810	.001
2-WAY INTERACTIONS	2.973	20	.149	37.585	.001
IFM ISPEED	.150	8	.019	4.754	.001
IFM IRCS	2.555	8	.319	80.749	.001
ISPEED IRCS	.268	4	.067	16.922	.001
3-WAY INTERACTIONS	.164	16	.010	2.592	.001
IFM ISPEED IRCS	.164	16	.010	2.592	.001
EXPLAINED	15.805	44	.359	90.924	.001
RESIDUAL	1.602	405	.004		
TOTAL	17.407	449	.039		

450 CASES WERE PROCESSED.
0 CASES (0 PCT) WERE MISSING.

* * * * * * * * * A N A L Y S I S   O F   V A R I A N C E * * * * * * * * *

```
                PSB       PROB SURV OF BOMBER FORCE
             BY IFM       FORCE MIX
                ISPEED    SPEED
                IRCS      RCS IN DB DOWN FROM REFERENCE
```

* *

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	7.244	7	1.035	148.178	.001
IFM	.016	3	.005	.750	.518
ISPEED	.982	2	.491	70.295	.001
IRCS	6.246	2	3.123	447.202	.001
2-WAY INTERACTIONS	1.198	16	.074	10.634	.001
IFM ISPEED	.049	6	.008	1.172	.321
IFM IRCS	.404	6	.067	9.649	.001
ISPEED IRCS	.735	4	.184	26.384	.001
3-WAY INTERACTIONS	.063	12	.005	.747	.705
IFM ISPEED IRCS	.063	12	.005	.747	.705
EXPLAINED	8.495	35	.243	34.753	.001
RESIDUAL	2.263	324	.007		
TOTAL	10.757	359	.030		

450 CASES WERE PROCESSED.
90 CASES (20.0 PCT) WERE MISSING.

AD-A115 698 AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOO--ETC F/G 15/7
DILUTE: A MINI-CAMPAIGN SIMULATION MODEL TO ANALYZE STRATEGIC P--ETC(U)
MAR 82 G J FERREN, R W GALLAS

UNCLASSIFIED AFIT/GST/OS/82M-6 NL

3 OF 3
AD A
115698

END
DATE
FILMED
07-82
DTIC

* * * * * * * * A N A L Y S I S   O F   V A R I A N C E * * * * * * * *

PSBBS PROB OF SURV OF BOMBERS AT BAND SAM
BY IFM FORCE MIX
ISPEED SPEED
IRCS RCS IN DB DOWN FROM REFERENCE

* *

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	18.246	7	2.607	409.173	.001
IFM	6.768	3	2.256	353.737	.001
ISPEED	.371	2	.186	29.148	.001
IRCS	11.114	2	5.557	872.353	.001
2-WAY INTERACTIONS	3.420	16	.214	33.555	.001
IFM ISPEED	.055	6	.009	1.437	.200
IFM IRCS	3.288	6	.548	86.030	.001
ISPEED IRCS	.077	4	.019	3.018	.018
3-WAY INTERACTIONS	.189	12	.016	2.475	.004
IFM ISPEED IRCS	.189	12	.016	2.475	.004
EXPLAINED	21.855	35	.624	98.023	.001
RESIDUAL	2.064	324	.006		
TOTAL	23.919	359	.067		

450 CASES WERE PROCESSED.
90 CASES (20.0 PCT) WERE MISSING.

* * * * * * * * * A N A L Y S I S O F V A R I A N C E * * * * * * * *

PSBTS PROB SURV OF BOMBERS AT TERMINAL SAM
BY IFM FORCE MIX
ISPEED SPEED
IRCS RCS IN DB DOWN FROM REFERENCE

* *

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	37.568	7	5.367	107.072	.001
IFM	.513	3	.171	3.438	.017
ISPEED	.358	2	.179	3.594	.029
IRCS	36.781	2	18.391	369.640	.001
2-WAY INTERACTIONS	.733	16	.046	.921	.546
IFM ISPEED	.219	6	.037	.735	.622
IFM IRCS	.296	6	.049	.993	.430
ISPEED IRCS	.203	4	.051	1.019	.399
3-WAY INTERACTIONS	.346	12	.029	.579	.858
IFM ISPEED IRCS	.346	12	.029	.579	.858
EXPLAINED	38.646	35	1.104	22.194	.001
RESIDUAL	14.776	297	.050		
TOTAL	53.423	332	.161		

450 CASES WERE PROCESSED.
117 CASES (26.0 PCT) WERE MISSING.

* * * * * * * * * A N A L Y S I S   O F   V A R I A N C E * * * * * * * * *

PSDAI   PROB SURV OF BOMBERS IN AI AREA
BY IFM   FORCE MIX
ISPEED   SPEED
IRCS   RCS IN DB DOWN FROM REFERENCE

* *

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	4.152	7	.593	29.213	.001
IFM	.299	3	.100	4.923	.002
ISPEED	1.353	2	.676	33.322	.001
IRCS	2.501	2	1.250	61.389	.001
2-WAY INTERACTIONS	1.402	16	.089	4.315	.001
IFM ISPEED	.460	6	.077	3.777	.001
IFM IRCS	.523	6	.087	4.293	.001
ISPEED IRCS	.419	4	.105	5.153	.001
3-WAY INTERACTIONS	.074	12	.006	.302	.989
IFM ISPEED IRCS	.074	12	.006	.302	.989
EXPLAINED	5.628	35	.161	7.920	.001
RESIDUAL	6.578	324	.020		
TOTAL	12.206	359	.034		

450 CASES WERE PROCESSED.
90 CASES (20.0 PCT) WERE MISSING.

* * * * * * * * * A N A L Y S I S   O F   V A R I A N C E * * * * * * * *

PSMAI   PROB SURV OF ALCMS IN AI AREA
BY IFM   FORCE MIX
ISPEED   SPEED
IRCS   RCS IN DB DOWN FROM REFERENCE

* *

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	10.259	7	1.466	724.290	.001
IFM	1.900	3	.633	313.049	.001
ISPEED	1.081	2	.541	267.113	.001
IRCS	7.278	2	3.639	1798.333	.001
2-WAY INTERACTIONS	1.807	16	.113	55.813	.001
IFM ISPEED	.182	6	.030	14.951	.001
IFM IRCS	1.204	6	.201	99.171	.001
ISPEED IRCS	.421	4	.105	52.066	.001
3-WAY INTERACTIONS	.224	12	.019	9.217	.001
IFM ISPEED IRCS	.224	12	.019	9.217	.001
EXPLAINED	12.290	35	.351	173.533	.001
RESIDUAL	.656	324	.002		
TOTAL	12.946	359	.036		

450 CASES WERE PROCESSED.
90 CASES (20.0 PCT) WERE MISSING.

APPENDIX I

MODEL VERIFICATION

This appendix includes computations and portions of computer outputs to support model verification. Included in this appendix is a sample output from Program PSI, Program SAX, and extracts of a TRACE report.

Program PSI

Program PSI uses the inputs of weapon yield (YIELD), height of burst (HOB), ground range miss distance (GR), and the parameters to the log-normal damage function α and β . These terms are discussed in detail in Chapter II. These inputs are used to determine the overpressure (Δp) and Probability of Damage (PD) on target. The program first scales HOB and GR for weapon yield as described in Chapter II. PSI then calculates the overpressure on target by using the curve fit to the overpressure curves shown in Figure 9. To calculate the Probability of Damage, PSI then uses a curve fit to the cumulative normal probability distribution. The curve fit equations are shown in Appendix E. In order to verify the output from Program PSI four sample cases are presented:

	YIELD	HOB	GR	α	β
Case 1	200KT	4000'	600'	2.197	.3
Case 2	1000KT	0'	4000'	2.079	.3
Case 3	200KT	4000'	3000'	2.197	.3
Case 4	200KT	4000'	6000'	2.197	.3

To calculate Δp and PD, HOB and GR are scaled for weapon yield. The following scaling equation (see Chapter II) was used:

$$\text{Scaled Distance} = \frac{\text{Actual Distance}}{(\text{YIELD})^{1/3}}$$

The scaled values for the four cases are shown below:

	Scaled HOB	Scaled GR
Case 1	684'	103'
Case 2	0'	400'
Case 3	684'	513'
Case 4	684'	1026'

Overpressure was then determined from the graph in Figure 9 using the scaled values as entering arguments. As discussed in Chapter II, Probability of Damage is a function of overpressure and follows a lognormal distribution. To "normalize" the overpressure, the following transformation to the standard normal distribution was used:

$$z = \frac{\ln(\Delta p) - \alpha}{\beta}$$

where:

z = normally distributed random variable with a mean of zero and standard deviation of one.

α, β = parameters of the lognormal distribution described in Chapter II.

Once the z random variable was calculated the Probability of Damage was determined by extracting the value from a normal probability table (Ref 31:468). The overpressure and Probability of Damage for each of

the four cases is shown below. The two columns on the right are the values of Δ p and PD obtained by the manual procedure described above. The two columns on the left were the values of Δ p and PD as output from Program PSI.

	PSI		MANUAL	
	Δ p	PD	Δ p	PD
Case 1	40.57	1.0	45	1.0
Case 2	74.57	1.0	75	1.0
Case 3	26.19	.9998	26	.9998
Case 4	13.68	.9186	16	.9724

All cases except Case 4 show exact agreement between the computer program and manual calculation. Case 4 differed slightly because of the slight inaccuracies incurred using the curve fit equation. This deviation does not impact the results of the model.

Program SAX

Program SAX is a mini-simulation of the SAM encounter. The program starts at the initial encounter range which is a function of the initial detection range and the time spent in the SAM queue. Once the initial encounter range is determined the single shot probability of kill (PKSS) is determined and is a function of range and either jamming-to-signal noise ratio (J/S) or signal-to-noise ratio (S/N). The penetrator is tracked until a PKSS of .2 is attained at which time the SAM begins to fire missiles. For a full description of the SAM encounter see Chapter II.

Shown below is a sample output for Program SAX. For this engagement the following inputs were used:

Type penetrator = 1 (indicates bomber)
Speed = 380 knots
RCS level = 1
Missiles Remaining on Launcher = 4
Offset distance = 10.0nm
Initial encounter range = 15.0nm
Time at initial encounter = 1000.00 (hours.minutes)
Time of exiting coverage = 1001.76 " "

The output:

```
ENTER TYPE PEN,SPEED IN KNOTS,RCS SET,MSLS
     62600 CM STORAGE USED.
     0.392 CP SECONDS COMPILATION TIME.
1,380,1,4
ENTER Y DIS,SRNG,TNOW,TIME OUT OF COVERAGE
?10.,15.,1000,1001.76


TIME     XRNG    AZ    IAZ  SIGMAT     CEP    PKSS  MSLS  LEAD ANGLE
   .25    9.6   46.3    5    20.0000   248.  .1856  4.     46.3
   .41    8.6   49.4    5    20.0000   231.  .2109  4.     49.4

FIRING POS. AT TIME  .4078947368421

    .72    6.6   33.4    6    35.0000   154.  .4138  3.      7.2
  1.06    4.5   24.0    7    40.0000   128.  .5372  2.      8.0
  1.37    2.4   13.7    8   500.0000    41.  .9994  1.      8.8

 PENETRATOR WAS KILLED BY SHOT  3
AT TIME   1001.374414455
TOTAL TIME IN COVERAGE  1.374414454698
     END  SAX
```

The column headings are defined below:

Time : elapsed time during the encounter

XRNG : distance remaining to exiting coverage

AZ : the relative bearing of the penetrator. Zero degrees is nose on to the site while 90 degrees is abeam the site. This relationship reverses during the firing sequence with zero degrees being the limit of the SAM azimuth coverage.

IAZ : used in determining the penetrator's Radar Cross Section (RCS). RCS is a function of azimuth and is divided into 10 degree increments. IAZ is the integer value of AZ rounded to the closest 10 degrees.

SIGMAT : the penetrator's RCS actually used. SIGMAT is a function of RCS level and azimuth.

CEP : SAM missile Circular Error Probable. CEP is a function of range and either J/S or S/N. The equations used are discussed in Chapter II.

PKSS : single shot probability of kill which is exponentially determined and is function of lethal radius (LR) and CEP. See Chapter II.

MSLS : missiles remaining on the SAM launcher.

lead angle : the number of degrees which the penetrator must be lead to affect an intercept. This is determined by proportional navigation and is a function of the encounter geometry and the relative velocity between the SAM missile and the penetrator. Lead angle has no meaning until firing commences.

The output shows how the site tracked the penetrator until a PKSS of at least .2 was attained. One notices that as the encounter progresses the XRNG is decreasing, IAZ is increasing, and RCS increases as the penetrator turns to a more broadside profile. The higher the RCS and the closer the range the smaller the CEP becomes. PKSS increases with decreasing CEP. Shots are fired until the penetrator is killed, leaves coverage, or the launcher runs out of missiles. There were three shots fired with the third shot resulting in a kill. This left one missile

remaining on the launcher. All calculations were verified with TI-59 hand calculator programs using the equations outlined in Chapter II.

TRACE Report

The following is an extract from a SLAM TRACE report. From the TRACE penetrator #63, a bomber, was selected as the example to be included in this appendix because it was successful in penetrating all the defenses and releasing all its weapons which were targeted in each zone. During this penetrator's travel through the network, every major portion of the network was excercised. The penetrator is followed from creation to termination. The following,then, is the saga of penetrator #63:

Elapsed Time	Node	Comments
0	1	Creation
	TGT1	Target Assignments
.09	SAM1	Queues up for encounter
2.00	ESC1	SAM was saturated. Entity departs BSAM with no encounter.
	Z1	Attacks Zone#1 - strikes target #14
	FTR1	Enters fighter threat
	ASN5	Sets the time for SRAM launches into Zones 2 and 3, and time of gravity weapon drops into Zone 4.
	ASN6	The times in and out of the first GCI encounter are calculated. .
8.85	FCAP	Queues up for a fighter
	CAP1	Fighter is immediately available. Entity is assigned to fighter group 1
13.25	AIG	Fighter encounter is over. Encounter duration was 4.4 minutes.
	ASN6	Entity survived encounter and is sent back for possible subsequent encounter. Times in and out of next GCI area are computed.

32.00	TMZN	Fighters were tied up. Entity waits until scheduled time at TSAM. Entity arrives to the terminal area.
32.01	TS14	Entity enters TSAM, Zone 4. Offset distance from SAM was approximately zero therefore entity enters SAM envelope immediately and queues up for TSAM encounter.
32.53	L14	Entity stays in queue .52 minutes before he is tied up with a launcher.
33.58		Survives the TSAM encounter Entity successfully releases 6 SRAM and 3 more gravity weapons.
	TZZZ	Penetrator #63 terminates the mission successfully.

VITA

Captain Randolph William Gallas

Randolph William Gallas was born on 16 July 1949 in Chambersburg, Pennsylvania. He graduated from high school in Shippensburg, Pennsylvania in 1967 and attended the Pennsylvania State University graduating in June 1971 with a Bachelor of Technology degree in Electrical Engineering. In 1971 he entered Officers Training School and was commissioned in October 1971. He attended Undergraduate Navigator Training and received his wings in August 1972. He then served as a KC-135 navigator and flight instructor with the 22nd Air Refueling Squadron, March AFB, California until 1977. He was then assigned as a squadron training flight instructor, and standardization and evaluation navigator with the 46th Air Refueling "Mosquito" Squadron and the 410th Bomb Wing, KI Sawyer AFB, Upper Peninsula of Michigan. He entered the School of Engineering, Air Force Institute of Technology in August 1980. He is married to the former Ann Marie Burkholder, and they have two daughters, Tina Marie and Melissa Ann.

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Captain George James Ferren

Captain Ferren was born in Lynn, Massachusetts on October 8, 1950. He graduated from Lynn English High School in 1968 and attended the University of Massachusetts at Amherst. He graduated in June 1972 with a Bachelor's degree in Operations Research and received his ROTC commission into the United States Air Force.

After completing navigator training at Mather AFB, Sacremento, California he was assigned to the 17th Bombardment Wing, Wright-Patterson AFB, Ohio as a Radar Navigator flying in the B52H. After a short tour of duty in the B52D at Utapao Airfield, Thailand, he was assigned to the 319th Bombardment Wing, Grand Forks AFB in July 1975 where he served as a squadron instructor Radar Navigator. Moving over into the 319th Bomb Wing Staff in May 1978, Captain Ferren completed his northern tier assignment as the Wing Missile Operations Officer in charge of SRAM operations. He entered the Air Force Institute of Technology in August 1980.

Captain Ferren is married to the former Carolyn F. Johnson of Sacremento, California. They have three children, William Andrew (12 years), Teresa Sharon (11 years), and Christine Aspacia (9 months).

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This study develops a computer simulation model of manned and unmanned penetrators in a strategic scenario in order to evaluate the effects of various force mix combinations of cruise missiles and manned bombers. The model is largely based on three generations of strategic weapons to be used in a strategic conflict. In general, the model uses data based on current, projected, and future technological developments in the area of strategic penetrators and uses this data to measure the synergistic effects of various combined manned/

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unmanned penetrator strike forces in terms of survivability and the ability to inflict the required level of damage to the enemy target base. The model, called DILUTE, is written in SLAM, using extensive FORTRAN inserts and is designed to allow for considerable flexibility and user control.

The experimental design uses a full factorial design with three factors: radar cross section, speed, and force mix. These factors are analyzed for significant effects on the value average probability of damage. In using an analysis of variance the three factors were found to be significant.

The results of the study indicated that significant differences do exist between force mix combinations of ALCM and manned penetrators, however the results are highly dependent upon the factors of radar cross section and speed. Bomber survivability against peripheral defenses of surface to air missile threats can be significantly enhanced if the bombers are used in concert with cruise missiles due to the defense dilution aspect of the ALCM. The same effect was determined in the airborne interceptor threat, as long as the airborne interceptor had a reasonable chance of detecting the ALCM. Enhancement of bomber survivability by ALCM dilution at the terminal surface to air missile threat was determined not to be statistically significant at the 1% level. Additionally, it was realized that pure forces dominate mixed forces; the dominant characteristics being electronic countermeasures for the bomber and saturation for the ALCM. Finally, the decisions on force mix are heavily dependent upon radar cross section and speed improvements, with the manned penetrator being a much more effective weapon system than the ALCM when technological improvements in speed and radar cross section are employed.